VIRGINIA DEPARTMENT OF ENERGY

DIESEL ENGINE MECHANIC CERTIFICATION STUDY GUIDE 2024

Commonwealth of Virginia
Department of Energy
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INTRODUCTION

Board of Coal Mining Examiners Certification Requirements

4 VAC 25-20-190. Underground Diesel Engine Mechanic

A. All maintenance work performed on diesel engines used to power equipment in underground coal mines shall be performed by, or under the direct supervision of, a person possessing a Diesel Engine Mechanic Certificate issued by the Board of Coal Mining Examiners (BCME). In addition, no operator of an underground coal mine in the Commonwealth of Virginia may use diesel-powered equipment in the mine without first employing a diesel engine mechanic who is certified by the BCME.

B. "Maintenance" shall include all the tasks required to be performed routinely to ensure that the engine exhaust emissions conform with the requirements of the laws and regulations of Virginia and MSHA, and with the maintenance recommendations of the manufacturer of the engine.

C. Applicants shall possess six months experience as a diesel engine mechanic, complete a diesel engine mechanic course approved by the Virginia Department of Energy (Virginia Energy), or possess appropriately related work experience approved by the chief. A one-year diesel engine mechanic program approved by the Coal Mine Safety may be substituted for the diesel engine mechanic experience.

D. Applicants shall pass the underground diesel engine mechanic and gas detection examinations.

E. The initial training course for diesel engine mechanics shall include at least 32 hours of classroom instruction and be taught by a certified instructor.

F. To qualify for approval by the chief, the content of the initial training course for diesel engine mechanics shall include, but is not limited to:
   1. Diesel engine principles
   2. Diesel fuel and fuel systems
   3. Engine exhaust systems
   4. State and federal diesel laws and regulations
   5. Safe use of equipment
   6. Emission controls, testing procedures, and record keeping
   7. Protection of health of workers exposed to diesel equipment

G. The annual continuing education course for diesel engine mechanics shall include at least four hours of classroom instruction and be taught by a certified instructor.

H. The content of the continuing education course shall include, but not be limited to:
   1. Diesel technology
   2. State and federal diesel laws and regulations
   3. Safe use of equipment
   4. Protection of the health of workers exposed to diesel equipment
   5. Required emission test procedures and record keeping

I. A Diesel Engine Mechanic Certificate shall remain valid until December 31 following the anniversary date of the initial training, providing the certification requirements are met, unless the certificate is revoked by the BCME.

J. The holder of the certificate shall renew the certificate by satisfactorily completing a diesel engine mechanic continuing education course approved by the chief and taught by a certified instructor.

K. The holder of the certificate shall submit documentation to Virginia Energy indicating the required continuing education has been completed before the expiration of the card.

L. Failure to complete the required education shall result in suspension of certification pending completion of continuing education. If the continuing education requirement is not met within two years from the suspension date, the certification shall be revoked by the BCME.

M. Virginia Energy shall send notice of any suspension to the last known address that the certified person reported to Virginia Energy in accordance with 4 VAC 25-20-20.I and to the last known employer address.

4 VAC 25-20-200. Diesel Engine Mechanic Instructor

A. Applicants shall have teaching experience and be a certified diesel engine mechanic or possess appropriately related work experience approved by the chief.

B. Applicants shall maintain the certificate by teaching at least one approved diesel engine mechanic course every two years or at least one approved diesel engine mechanic continuing education course every year.

C. Documentation shall be submitted to Virginia Energy indicating the required teaching has been completed.

D. Failure to complete the required education shall result in suspension of certification pending completion of continuing education. If the continuing education requirement is not met within two years from the suspension date, the certification shall be revoked by the BCME.

E. Virginia Energy shall send notice of any suspension to the last known address that the certified person reported to Virginia Energy in accordance with 4 VAC 25-20-20.I and to the last known employer address.

Diesel Engine Mechanic Certification Requirements

Photo ID Required

Article 3 of the Coal Mine Safety Laws of Virginia establishes requirements for certification of coal mine workers. The certification requirements are included in §45.2-515 through §45.2-534 in which the Board of Coal Mining Examiners is established for the purpose of administering the certification program. The Board has promulgated certification regulations 4 VAC 25-20, which set the minimum standards and procedures required for Virginia coal miner examinations and certifications.

CERTIFICATION CLASSIFICATION: Underground Diesel Engine Mechanic
This certification authorizes the holder to:

- Perform maintenance work on diesel engines in underground coal mines as recommended by the manufacturer of the engine

APPLICATION/EXPERIENCE REQUIREMENTS:

- Application (BCME-1) and $40.00 fee 5 working days prior to examination
- Six months experience as an underground diesel engine mechanic or complete a diesel engine mechanic course approved by the Coal Mine Safety or possess appropriately related work experience approved by the Chief of the Coal Mine Safety

NOTE: Experience must be submitted within 5 years of passing the examination. After 5 years records are destroyed. Must reapply if future certification is desired.

- Hold a General Miner Certification
- Current first aid training (MSHA 5000-23 Annual Retraining or New Miner inexperienced Training acceptable)

EXAMINATION REQUIREMENTS: A score of 80% on each element of the examination

ELEMENTS OF EXAM	NUMBER OF QUESTIONS
• Emissions Testing (ET)	20
• Fuels and Emissions (FM)	20
• Internal Combustion (IC)	20
• Preventive Maintenance (PM)	20
• Federal Regulations (FR)	20
• Virginia Rules & Regulations (VR)	20
• Gas Detection - practical demonstration	

continued

COAL MINE SAFETY
BOARD OF COAL MINING EXAMINERS
CERTIFICATION REQUIREMENTS
http://www.energy.virginia.gov

RECOMMENDED REFERENCE/STUDY MATERIALS:

- Coal Mine Safety Laws of Virginia
- BCME Requirements
- Title 30 CFR Parts 36, 75
- Rules & Regulations Governing the Use of Diesel-Powered Equipment
- Diesel Engine Mechanic Study Guide
- Practical Ways to Reduce Exposure to Diesel in Underground Coal Mines Exhaustion in Mining– A Toolbox
- Mine Gases Packet

The above-mentioned study materials are available at the Virginia Department of Energy's Big Stone Gap Office, Customer Assistance Center (276) 523-8233 and Lebanon Field Office (276) 415-9650.

*4 hours annual continuing education required to update this certification.

VIRGINIA DEPARTMENT OF ENERGY
DISCLAIMER

Article 3 of the **Coal Mine Safety Laws of Virginia** establishes requirements for certification of coal mine workers. The certification requirements are included in §45.2-515. through §45.2-534. in which the Board of Coal Mining Examiners is established for the purpose of administering the certification program. The Board has promulgated certification regulations 4 VAC 25-20, which set the minimum standards and procedures required for Virginia coal miner examinations and certifications.

The Virginia Department of Energy developed this study guide to better train coal miners throughout the mining industry. The study guide material should be used to assist with the knowledge necessary for coal mining certifications. The material is not all-inclusive and should be used only as an aide in obtaining knowledge of the mining practices, conditions, laws, and regulations. This material is based upon the Coal Mining Safety Laws of Virginia, Safety and Health Regulations for Coal Mines in Virginia, Title 30 Code of Federal Regulations (30 CFR), State and Federal Program Policy Manuals, and other available publications. Nothing herein should be construed as recommending any manufacturer's products.

The study guide and materials are available at the Virginia Department of Energy. Any questions concerning the study guide should be addressed to the Regulatory Boards Administrator at the Big Stone Gap Office.

UNIT I
DIESEL ENGINES

A. HISTORY

In the late nineteenth century, research was conducted to develop more efficient engines that would operate on energy sources other than steam. One of the pioneers was Dr. N. A. Otto. Dr. Otto succeeded in developing a gasoline engine that operated on a cycle he had discovered in 1876. The Otto Cycle is the basis on which gasoline and diesel engines operate today.

Once the Otto cycle was established, researchers began searching for methods to satisfactorily ignite a mixture of air and fuel. One method was to compress the air in a cylinder so tightly that extremely high temperatures would be produced. Fuel would be injected into this very hot air and would burn almost immediately. The expansion of the burning air and fuel produced power. This type of engine is called the **compression-ignition engine**. However, several problems arose. The principal ones were a lack of building materials that would hold up under high temperatures, and difficulties in injecting fuel into a high-pressure area.

Credit for developing the compression-ignition engine is given to a German engineer named **Rudolph Diesel**. Initially, he attempted an engine that ran on coal dust, but these engines exploded. In 1894, he successfully switched to a liquid fuel. His engine was more economical and efficient than the known engines of his day. Finally, in 1895, Diesel was granted the U.S. patents on the compression-ignition engine.

By 1900, the diesel was widely used in industrial plants in Europe. These diesel engines, being large and heavy, were used only in stationary applications. As diesel engine technology matured, the power-to-weight ratio increased. By 1924 the first diesel-powered ocean liner was launched, in 1925 a diesel-powered bus, and in 1929 a diesel-powered truck. These engines were still too large and bulky for automobile use, although Peugeot attempted the feat in 1922.

In 1927, the Robert Bosch Company began making fuel injection equipment for diesels. This was important because Robert Bosch was able to mass-produce fuel injection equipment that allowed diesel use in a variety of applications. Furthermore, his company granted licenses to manufacturers in other countries.

This created greater production facilities and allowed the diesel engine to become a worldwide power source.

By the 1930's, diesel engines, in part, were advanced by the Cummins Engine Company, Inc., by racing diesel-powered cars. Such cars qualified and ran in the 1931, 1934, 1950, and 1952 Indianapolis 500-mile races. In 1931, a Cummins diesel-powered car completed the Indianapolis 500 without a pit stop. In 1952, Cummins entered the Indianapolis 500 with an aerodynamic, low silhouette, turbocharged, diesel-powered race car. The engine produced 430 horsepower at 4,500 RPM (the stock engine at that time produced 125 horsepower and 2,500 RPM). It won the pole position with a new four-lap record of 138.010 mph. However, during the race, tire rubber dust from other cars gathered in the turbocharger, choking off the air supply. Still running, but smoking, the car was pulled from the race in the 72nd lap and was never raced again.

After World War II, gasoline was expensive in markets other than the United States, forcing Europe and Japan to develop economical diesel engines for passenger cars and small trucks. In the United States, diesel engine development advanced in the area of construction and large truck equipment. Car buyers in the United States chose power over economy. However, if you wanted a diesel automobile, there were but very few, expensive choices.

In 1973, the Arab oil embargo forced a dramatic increase in gasoline prices. Fuel economy was suddenly an important factor in the operation of motor vehicles. Manufacturers looked at alternative sources and concluded that the diesel engine had the capability to produce high mileage ratings without necessitating expensive or exotic technology.

In 1977, Volkswagen made the first lightweight, diesel economy car for the United States. General Motors, in the following year, produced a V-8 diesel for its full-sized cars. Today, there are various manufacturers producing a variety of diesel engines for a variety of passenger cars, small trucks, large trucks, and industrial equipment. Current information indicates that the diesel engine option will continue to expand in the future.

B. HISTORY OF DIESEL EQUIPMENT IN VIRGINIA

Regulations Governing the Use of Diesel-Powered Equipment in Underground Coal Mines in Virginia

4 VAC 25-90

Initial regulations governing used of diesel equipment underground were implemented on June 16, 1985. The regulations were amended in 1991, and major amendments were implemented in 2001. On September 8, 1985, the first piece of diesel equipment was approved for use underground. The Jeffrey, Ram Car was approved for use at Westmoreland Pierrepont (West Mine). As of 2024 there have been over 2,100 pieces of diesel equipment (including engine changes) approved for underground use in Virginia coal mines. Diesel equipment approved for use include air compressors, coal haulers, roof bolters, generators, service jeeps, track cleaners, locomotives, rock dusters, personnel carriers, fire cars, shield haulers, utility vehicles, and scoops.

The statutory authority to approve and use diesel equipment in underground coal mines in Virginia is covered in section 45.2-824. of the Coal Mine Safety Laws of Virginia.

45.2-824. Diesel powered equipment

Diesel powered equipment may be utilized underground with the written approval of the Chief. The Chief shall promulgate regulations necessary to carry out the provisions of this section. The regulations shall require that the air in each travel way in which diesel equipment is used, and in any active workings connected thereto, be of a quality necessary for a safe, healthful working environment. The minimum quantity of ventilating air that must be supplied for a permissible diesel machine in a given time shall conform to that shown on the approval plate attached to the machine. Every diesel machine or piece of equipment shall be maintained in such manner that the exhaust emissions meet the same standards to which the machine or equipment was manufactured.

C. APPLICATION

The diesel is a versatile engine. It is capable of producing from 1 to 50,000 HP. This wide range allows the diesel to be used to power ships, generators, construction equipment, farm equipment, large trucks, as well as passenger cars and small trucks. Not only is the diesel engine adaptable, but also is more economical and dependable than other power sources. Hence, diesels completely dominate areas such as the large truck class and construction equipment. The diesel engine is designed for specific applications, thus creating numerous differences among diesel engines. The passenger car or small truck uses a high-speed diesel. The high-speed diesel differs significantly from the large, slow-speed diesels used in large trucks. The high-speed diesel:

- Has a higher RPM limit (approximately 5000 RPM vs. 2100 RPM)
- Does not produce a high sustained torque curve
- Uses a different combustion chamber
- Uses different starting aids
- Frequently uses different fuel systems

These differences are the result of the application, since the high-speed diesel is designed to give the same performance and feel as a gasoline engine. It is not designed to haul heavy loads over an extended period of time.

D. ADVANTAGES OF THE DIESEL ENGINE

The basic advantages of the diesel engine are low fuel consumption (greater thermal efficiency), less fire hazard, and lower emission levels.

The fuel consumption: The three primary factors for the diesel engine's low fuel consumption are air-fuel ratio, compression ratio, and low pumping losses. The air-fuel ratio is the required amount of air to fuel needed to produce combustion. In the gasoline engine the air-fuel ratio is usually from 13:1 at idle to 17:1 under light cruise operation. The diesel ranges from 100:1 at idle to 20:1 under acceleration. Only the proper amount of fuel needed is injected into the cylinder. The compression ratio is the comparison of cylinder volume when the piston is at bottom dead center (BDC) to cylinder volume when the piston is at top dead center (TDC). The formula is this:

$$\frac{\text{volume at BDC + volume at TDC}}{\text{volume at TDC}} = \text{compression ratio}$$

Today's gasoline engines have approximately an 8:1 compression ratio. The diesel ranges from 17:1 to 23:1. The compression ratios of small, high-speed diesels used in passenger cars range from 21:1 to 23:1. The higher the compression ratio, the more efficient the engine will operate because more energy is being extracted from the fuel.

Pumping loss is the amount of energy expended when pulling air into the cylinder and pushing the exhaust gases out. The gasoline engine has a throttle restriction, but the diesel engine does not. The greater the restriction, the less efficient the engine is because it takes power to overcome the restriction. The diesel engine does not waste energy trying to pull air past the throttle value; thus, it has less pumping loss.

Compared to the gasoline engine at idle and deceleration, the diesel can be 40% to 50% more efficient. Also, very little or no fuel is injected into the cylinder under these conditions.

Very low pumping losses, very lean air-fuel ratios, and high compression ratios help make the diesel more **thermally efficient**. That is, of the total amount of energy available in the fuel, the diesel will convert more of the fuel's heat energy into usable power than the gasoline engine. Another advantage is that diesel fuel contains more energy per gallon than gasoline. It takes less diesel fuel to do the same amount of work as compared to gasoline.

Less fire hazard: Diesel fuel does not evaporate as readily as gasoline. **The ease with which a liquid evaporates is called volatility**. Gasoline is very volatile compared to diesel fuel and will ignite much more easily. This is no reason, however, to handle diesel fuel any less carefully than gasoline.

Lower emission levels: Hydrocarbons are present in fuel that has not been burned. Carbon monoxide is fuel that has been partially burned. Because the diesel can draw in a full amount of air and can run on very lean mixtures, it can burn the fuel more completely. The diesel also produces less oxides of nitrogen (NOx). These oxides of nitrogen are formed when combustion temperatures are above approximately 2500 degrees Fahrenheit at which point the oxygen and nitrogen combine. The diesel does not produce as much NOx as the gasoline engine because the peak cylinder temperature is not as high, slowing the chemical formation of NOx.

Exhaust smoke and odor: Anyone who has followed a diesel-powered vehicle, particularly one with a malfunction, knows that the diesel produces smoke and has a unique odor. The black smoke most often visible is soot (particulates). This is a result of the fuel not mixing and burning properly or insufficient air to complete the combustion process. The diesel engine however does emit some particulates even when operating normally. Engineers continue to work on ways to resolve this problem.

White smoke is formed when the engine is operated under low temperatures, light load, or excessive ignition delay. The white smoke is air mixed with diesel fuel that has not been burned. This smoke is also normal when first starting a diesel but should clear up as the combustion chamber heats up.

A blue smoke is caused by excessive oil consumption. The odor, like the smoke, is a characteristic of the diesel engine design and the combustion process. Some odor, of course, is normal.

E. DISADVANTAGES OF THE DIESEL ENGINE

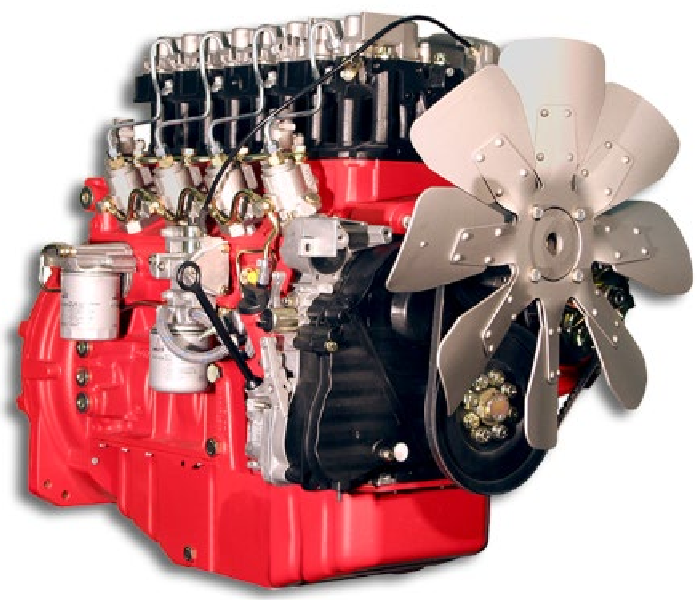
The following disadvantages of the diesel engine can be attributed to the diesel's characteristics or to the subjective opinion of the owner.

Diesel engine construction costs are higher. Because the diesel puts more stress on its components, the engine must be constructed from special materials. The quality of the material must be exact, and the parts must be fitted together with very little tolerance for error, resulting in higher assembly costs. Special items must be added. For example, a heavy-duty starting system must be used. Extra sound-insulation material is needed. All these items increase production cost.

Cold Weather Starting: Diesel engines use the heat of compression to ignite the fuel. The colder the air temperature, the harder it is to build up enough heat for ignition. To aid cold weather starting, manufacturers have added special starting aid packages. These packages may include an engine block heater, special fuel heaters, a high-power starting system, and a glow plug system. These features are designed to add heat to the engine or provide extra starting power. Some tractor and large truck diesel engines may use ether or have an air preheater. The ether works because the compression ratio in the large diesels is generally lower then 19:1.

Engine noise: Diesel engines produce a knock, particularly at idle, that is very noticeable. This is due to the high compression and the nature of the combustion process. This knock is particularly noticeable in cool weather because of uneven combustion. Engineers try to limit this noise as much as possible by adding special sound barriers to the engine. As a technician you must listen to the different sounds the diesel makes and train your ear to pick out the abnormal noises.

Low horsepower-to-weight ratio: The components of the diesel engine must be made durable enough to withstand the tremendous stress of the diesel combustion process. The diesel engine weighs more than the gasoline engine. Since the diesel engine weighs more, and sound-deadening insulation is needed, the chassis must be stronger and heavier to accommodate the extra weight. The top RPM of the diesel engine is limited because of the nature of the combustion process. This limits the amount of horsepower it can produce. When compared to the gasoline engine, the diesel engine has a low power-to-weight ratio. The horsepower-to-weight ratio can be increased by using lightweight materials and by adding turbochargers, but these also increase cost.



DEUTZ 2011 (Tier 2, 3, & 4i)

UNIT II
INTERNAL COMBUSTION

A. ENERGY CONVERSION

The diesel engine is an internal combustion, compression-ignition, heat engine. It is capable of **converting the fuel's heat to kinetic energy.**

B. BASIC ENGINE COMPONENTS

The major components needed to perform the combustion process are the engine block, cylinder head, piston assembly, crankshaft, connecting rod, camshaft and valve train assembly, and flywheel.

The engine block is the main structural member housing other components or having components fastened to it. The block provides the basic cylinder shape.

The barrel or bore in which the piston moves may be either integral with the male cylinder blocks or it may be a separate liner, which is also known as the sleeve. The construction first mentioned has the advantage of lower cost but has the disadvantage of not being replaceable. Most diesel engines have replaceable sleeves. When cylinders become worn, it is a relatively simple matter to remove the worn sleeve and install a new one. This restores the cylinder bore to its original condition. When the cylinder bore is an integral part of the cylinder block, and the cylinder becomes worn, reconditioning is necessary. In some cases, the machining can be done without removing the engine from the installed position by means of portable conditioning equipment. In the case of larger diesel engines, it is necessary to take the cylinder block to the machine shop, which is a costly operation.

Another advantage of the cylinder sleeve design is the sleeves can be manufactured of special alloys, while the cylinder block can be produced from lower cost material.

At the top of the cylinder is the **cylinder head**, which is bolted tightly to the engine block. The cylinder head contains the intake and exhaust valves, a nozzle, and (on some engines) the camshaft.

Piston: The piston is the only part in the combustion area designed to move when combustion occurs. With compression pressures reaching 900 psi and exhaust temperatures approximating 100 deg. F., diesel engine pistons are subjected to severe operating conditions. The pistons must be designed to withstand such conditions. Consequently, they are heavier than the familiar gasoline engine piston and have special provisions for cooling.

Aluminum and cast iron are generally used to manufacture diesel pistons. In some instances, large pistons are assembled which have a crown made of steel forging or cast steel. Another design provides a cast iron or heat-treated steel-forging insert for the piston pin insert. Inserts made of NERESIST (a nickel alloy), other alloys, and cast iron are also used as inserts for top ring grooves in aluminum alloy pistons as a reinforcement and wear reducing feature. Another way to control expansion is the installation of alloy steel braces placed across the piston pin bosses. Steel rings are also used in the piston crown for added strength.

Aluminum has several advantages as piston material. It is lighter than cast iron, weighing .097 lb. per cu. in. In addition, it has excellent heat conductivity, nearly twice as much as cast iron. The strength of aluminum decreases faster than cast iron as its temperature increases and it is necessary to use heavier sections to obtain the strength needed to carry heavy loads. The lighter weight of aluminum is important from the standpoint of vibration, and the load on the bearings and crankshaft.

While the wear of aluminum pistons in some installations may be greater than cast iron, this is offset by the fact that the aluminum pistons, because of the greater heat conductivity, are less subject to scoring. Aluminum melts at a temperature of 1260 deg. F. and cast-iron melts at 2768 deg. F. The temperature at the top of an aluminum piston can be such that the metal approaches a malleable condition. Consequently, the force of combustion tends to crush the upper compression ring groove and nullify the effectiveness of the compression ring.

Some diesel engine pistons have flat crowns. Others are formed to provide the combustion chamber with turbulence during the combustion process. For example, the M combustion chamber system has a spherical chamber, which is formed in the crown of the piston. Some engines use a precombustion chamber and a flat top piston.

Piston Rings: There are many different designs of piston rings, but there are two main classifications: compression rings and oil rings. As the names imply, compression rings are designed primarily to seal compression, so it does not pass the pistons. Oil rings are designed to control the amount of oil on the cylinder walls so that there is enough for lubrication.
Both types of rings are designed so the diameter before installation is slightly larger than that of the cylinder bore. When installed and the engine is at operating temperature, ends of the rings will not contact each other.

Most manufacturers place great stress on the rings exerting even pressure against the cylinder wall for the full circumference. When pressure varies, points of the greatest pressure will receive maximum wear. Other areas may not contact the wall and combustion leakage will occur.

Cast iron is the conventional material used for piston rings, although narrow steel bands are also used. In the case of oil control rings, the two steel runners will be separated by a crimped expander which, in addition to exerting radial pressure, also serves to keep the steel runners pressing against the upper and lower walls of the ring groove. The compression ring with an inside bevel, utilizes gas pressure to force the bottom edge of the ring to contact the cylinder wall with high pressure. This helps to seal against compression losses.

Several advantages are claimed for the keystone form of compression rings. Because of its wedge or keystone shape, the forces of compression create a certain degree of motion between the ring and the piston. This action is claimed to free the ring of carbon accumulation, thereby helping to prevent sticking. Compression rings are often chrome plated or molybdenum coated to provide increased life and greater freedom from scoring.

There are a large number of oil control rings, many are of two or more segments, usually they have some form of expander. Some designs have slots or holes through the ring. Excess oil from the cylinder walls passes through such holes and then through drain holes in the back of the ring groove in the piston. Excess oil is returned to the crankcase. Some oil rings also act as a scraper ring which scrapes excess oil from the cylinder walls into a beveled groove in the piston, provided with drain holes.

It is important the shape of the ring conform to the shape of the cylinder. Theoretically, this is circular, but operating conditions and variations in coolant temperature frequently cause the shape of a cylinder to vary from a true circle. Piston rings are, as a result, often designed with a degree of feasibility so they will conform to such changes.

Piston Pin: Piston pins, also called wrist pins, form the connection between the upper end of the connecting rod and the piston. The design is such that the piston can swing back and forth (oscillate) in a small area about the pin and the rod. Piston pins are usually of tubular construction to keep the weight to a minimum. The load it must carry determines the diameter. The load includes combustion pressure and inertial loads resulting from the weight of the piston and the speed. The diameter of the pin is usually larger for the diesel engines in proportion to the bore, than gasoline engines, because of higher combustion pressures. Thickness must be adequate to provide sufficient strength to withstand the loads, otherwise the pin will deform. Piston pins are always casehardened and ground to finish size, which maintain extremely close limits.

There are three main methods of mounting the pin in the piston and connecting the rod. The problem is difficult as the assembly is subject to large inertial loads, rapid acceleration, and deceleration. The weight must be kept to a minimum and the pin must be prevented from moving sideways, otherwise it will score the cylinder wall. As the piston pins have oscillating motion in the bearing surface and not continuous rotating motion, as is the case of the crankshaft, the steel piston pin can bear directly in an aluminum piston, or in bronze bushings in either cast iron or aluminum pistons. In some cases, needle bearings have been used on piston pins. Needle bearings naturally require hardened inner and outer races. As the piston pins are always casehardened, they serve as the inner races. A hardened bushing is used for the outer race.

Connecting Rod: The piston rod or connecting rod is either an I-beam or round tubular section, which connects the piston to the crosshead on engines of such design. Its motion is straight reciprocating, and it may contain passage for lubricating and cooling oil. The crosshead transmits the motion from the piston rod to the connecting rod, which in turn is connected to the crankshaft. The crosshead in such designs absorbs the side thrust usually taken by the piston in conventional construction.

Crankshaft: The crankshaft, as its name implies, is made of a series of cranks, one for each cylinder in the case of in-line engines. In the case of V-type engines, each crank will serve a pair of cylinders. The function of the crankshaft is to convert the reciprocating motion of the piston and its connecting rod, into rotating motion, which is needed to drive generators, pumps, ship propellers, and the wheels of automobiles and trucks. The throw of the crankshaft is equal to the stroke of the engine (i.e. the distance the piston moves from the top of the stroke to the bottom of the stroke).

The crank arrangements of two-stroke cycle engines are different than those of a four-stroke cycle engine with the same number of cylinders. For example, the usual arrangement of the crank throws off a four-stroke cycle six-cylinder in-line engine to have the throws 120 degrees apart, using a firing order 1-5-3-6-2-4. To use that crankshaft in a two-cycle engine, it will be necessary to have two cylinders fire at the same time. This would largely nullify the advantage of multicylinder construction.

The crankshaft of a six-cylinder two-cycle in-line engine will be arranged with the crank throws 60 degrees apart. This crankshaft is used with a firing order of 1-4-5-2-3-6, or 1-6-2-4-3-5 is also possible. In the case of the five-cylinder, four-cycle engine, the crank throws are 72 degrees apart. The firing order is 1-2-4-5-3, with a firing interval of 144 degrees.

Any rotating mass has to be balanced to keep vibration to a minimum. Consider that the crankshaft on a single cylinder engine has a single crank throw. To attain balance, an equal weight must be placed opposite the crank throw. A state of unbalance causes a centrifugal force to be formed which increases with the speed of rotation. Centrifugal force causes vibration and increases the load on the main bearings. The centrifugal force in the case of the crankshaft is counterbalanced by weights placed opposite the crankpin. Such weights create an equal and opposite force so the two forces counteract each other. When calculating the weight required obtaining balance, it is also necessary to include a portion of the reciprocating weights of the piston and connecting rods. Balancing crankshafts is a precision operation and can be done to a fraction of a gram with precision balancing equipment.

The forces considered so far are known as inertial forces. In four-cycle engines with more than four cylinders, the crank throws can be arranged so that the inertial forces will balance each other.

In addition to the inertia forces, forces also are created by the ignition of the fuel acting on the piston and in turn on the crankshaft. These tend to twist the crankshaft and cause what is known as torsional vibration. In general, longer crankshafts create greater torsional vibration. Adding vibration dampers, which are attached to the front end of the crankshaft, can minimize torsional vibration. Another type of damper consists of a flywheel ring, which is bonded to the hub of a thick layer of rubber.

A drive flange on the rear is used to transmit the crankshaft power into a torque converter, manual clutch and flywheel. **A flywheel is a heavy metal disc that stores kinetic energy.** The flywheel is necessary to keep the engine turning when power is not being produced.

Valves and Valve Seats: Because of the extreme operating temperatures, excessive gas pressures, corrosive quality of fuel, and hammering due to the high pressure of the valve springs, it is essential that diesel engine valves be constructed of special alloys. The effects of the temperature variation are particularly severe. With regard to gas pressure, this can easily exceed 2800 lbs. on a 2 in. diameter valve head. On a 2½ in. valve, this could reach 4350 lbs. Naturally, valves need to be designed to withstand such pressures.

To withstand high temperatures, many diesel exhaust valves are made of special alloy steel having a high resistance to heat. The edge (margin) of valves for diesel engines also is much thicker than is customary for valves in gasoline engines. Some diesel engine valves have hollow stems partially filled with mineral salts, which help to dissipate the heat. Engineering tests show that over half the heat leaves the valve through the valve face.

Since a large portion of the heat from the valves is dissipated through the valve head and seat, it is essential that particular attention be paid to the width of the seat. While a wide seat has the advantage of being able to conduct a greater amount of heat, it has the disadvantage of holding greater amounts of carbon, which will cause leakage. On the other hand, narrow valve seats will more quickly provide a pressure resistant seal. Compromise is, therefore, necessary. A seat width of approximately 1/8 in. is customary for many high-speed engines. Some engine specifications call for a seat width of 1/16 in. to 3/32 in. for both two-valve cylinder heads and the four-valve cylinder heads.

Valves are often two-piece construction with the valve head and neck being one portion, and the stem the other. The best material for each portion can be selected. Stems are often made of alloy steel, which operates in a relatively cool area, and provide good bearing qualities for reciprocating motion in the valve guide. The valve head, as previously indicated, must withstand high temperatures of exhaust gases, high pressures, pounding and the corrosive action of burned fuel, and is made of special alloy steel to withstand such conditions.

Valve seat inserts are provided in many engines, so seat life is extended. They also have the advantage of being replaceable. Several different types of material are used for valve seat inserts, including special alloys of cast iron for intake valve seats; for exhaust valve seats stellite and hardened chrome vanadium steel are used. Such inserts are installed with an interference fit.

The angle of the valve face and valve seat varies with different engine designs. Seat angles are usually either 30 or 45 degrees. While many valves and seats have the same angle (i.e. either 30 or 45 degrees), some valves have a face angle one-half degree less than the angle of the seat. This is done to provide quicker seating of the valve when the engine is placed in service. In the design of automotive diesel engines, some manufacturers favor 30 degrees valve seats while others use 45 degrees.

Valve Guides: Replaceable valve guides are provided for most engines. These not only provide a guide and bearing for the valve stems, but also aid in conducting the heat from the stem to the water jacket which surrounds the guide.

A long valve guide is desirable because they provide adequate bearing area for the valve stem and transfer heat away from the valve, but a long guide is more likely to cause valve sticking. This is particularly true in the case of exhaust valve guides when they are extended into the port toward the valve head. For that reason, many exhaust valve guides are cut off flush with the head boss in the port. Counter boring of the guide is also used as an aid against sticking.

Rotators and Spring Retainers: In the valve mechanism, the valve does not rotate; instead, the valve face strikes the valve seat in the same area. Under overload operating conditions, valve head temperatures will often reach the 1600 degrees F. range. As the temperatures rise, valve deterioration increases. Such deterioration results from combustion products forming on the valve face in non-uniform patterns. This permits blow by gases to pass through and increases the temperature of the valve head resulting in valve failure. Furthermore, the temperature around the edge of exhaust valves varies. These two conditions contribute to valve burning. This is further augmented by the fact that valve guide wear is normally uneven. Rotating the valve will wipe off combustion accumulations, produce more uniform temperatures around the circumference of the valve head, and result in even distribution of wear in the valve stem and valve stem guide.

There are several different designs of valve rotators. The rotator is used in conjunction with a special valve spring cap. The valve rotator includes six spring-loaded steel balls in individual grooves. The grooves are tapered so the balls aid rotation in one direction only, on each downward stroke of the exhaust valve. When the valve closes, rotation in the opposite direction is prevented since the narrow ends of the grooves restrict movement of the steel balls. The deflector is designed to deflect hot gases away from the valve stem and guide, reducing the formation of carbon.

Cam Followers: Cam followers, **commonly called valve lifters**, are the part of the valve operating mechanism that changes the rotary motion of the camshaft to reciprocating motion to open the valve. The cam followers ride the cam and are raised by the section of the cam as the camshaft rotates. Three types of cam followers or valve lifters are used. The mushroom type follower is the simplest type of lifter. The roller lifter has the advantage of reduced friction. A rocker mounted roller lifter design has the advantage of not producing side thrust. Side thrust can become excessive with some types of high lift cams. Followers are usually made of carbonized low carbon steel. In some cases, the followers are given surface treatment, such as chrome plating, to provide a more durable working surface.

Rocker Arms: When the camshaft is in the crankcase and the valves are overhead, a push rod is used to transmit motion of the cam and lifter to a rocker arm on the cylinder head. The motion of the rocker arm opens the valve. In the case of overhead camshafts, the cams operate directly on the followers, or in some designs the cams first operate on a rocker lever. Parts of valves may also be operated simultaneously from a single push rod by using a bridge or crosshead. It will be noted that the rocker arm actuated by the push rod, in addition to depressing one valve also operates another rocker arm. This in turn opens the second valve.

Valve Springs: In order to close the engine valves after being opened by the action of the cam, coil springs are provided. The valve springs are made of special alloy steel designed to withstand heat, corrosion, and continued flexing. To reduce valve flutter that may occur (particularly at high speeds), it is customary to wind the coils closer at one end of the spring than the other. Spring dampers are used for the same purpose. Tapered springs or two springs, one within the other, are also used to dampen the flutter.

Camshaft: Camshafts usually are forgings but, in some cases, they are castings. The purpose of the camshaft is to open the valves. Cams usually contact valve lifters, which open the valves by means of push rods and rocker arms. The cams are mounted in the crankcase and are driven directly through gears. In some engines, however, the camshafts are mounted above the cylinder head. Each cam contacts a follower, which contacts the valve stem. This design eliminates the customary push rods and rocker arms. Caterpillar uses a dual overhead camshaft on several of their engines. One camshaft operates two intake valves per cylinder, while the other operates two exhaust valves per cylinder.

Camshafts are usually mounted in sleeve type bearings. The contour of the cams is dependent on the timing desired. In small and medium size engines, the cams are forged or cast integral with the shaft. On larger engines the shaft may be built up in sections, or individual cams may be assembled on the shaft.

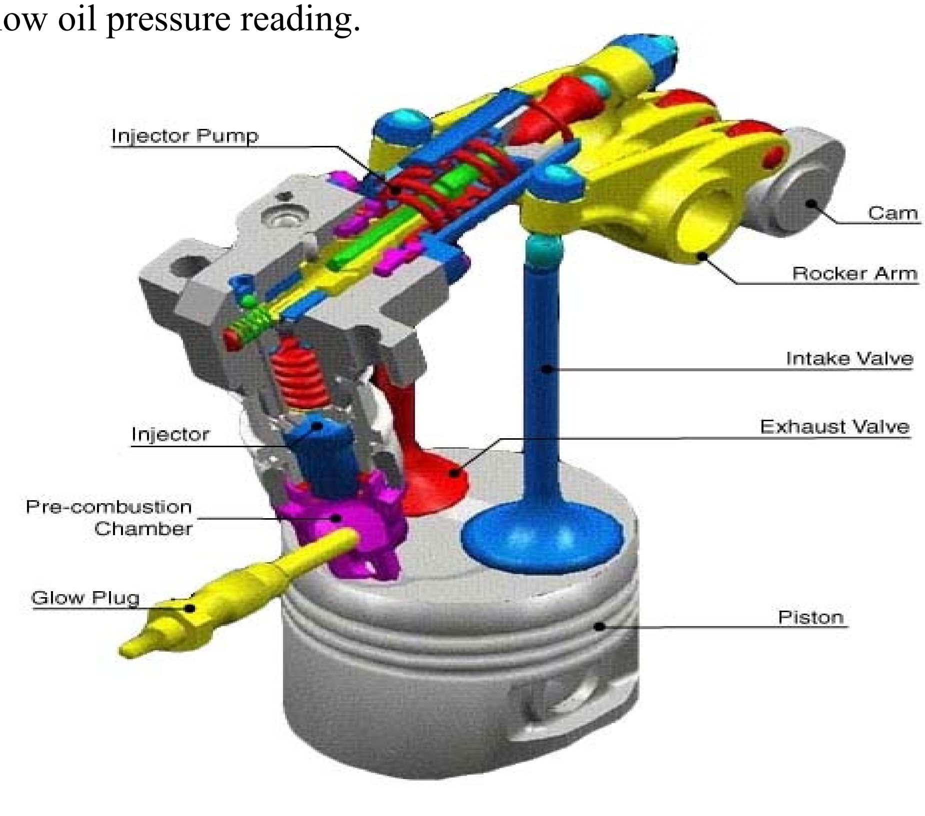
The Lubrication System: The purpose of the lubrication system is to distribute oil, lubricate, and reduce friction to key areas throughout the engine. Major lubrication components used on diesel engines are the crankcase sump pan, oil pump with pressure regulator, oil pump drive mechanism, oil cooler, oil cooler bypass valve, oil filter, oil pressure sending unit, and the piston cooling jets. The piston cooling jets spray oil underneath the piston to carry away heat and lubricate the wrist pin.

Bearings: Main and connecting rod bearings used in modern day engines are precision constructed that consist of a hard metal backing and have a facing of bearing metal. The backing material may be either bronze or steel. Occasionally, cast iron is used as backing on large engine bearings. Steel is the most common material. Such bearings are often referred to as steel backed bearings, or precision bearings. Many conditions have to be satisfied by the materials used for main and connecting rod bearings. The bearing surface should be capable of absorbing tiny particles of material, which result from normal wear of parts also known as embeddability. Bearing material must be strong enough to withstand the imposed loads. This condition is known as fatigue strength.

One of the first materials used as a bearing surface for main and rod bearings was babbitt, an alloy of tin, with copper and antimony and is still used today. It has either steel or bronze backing. A later type of babbitt, in which lead is substituted for tin, is known as lead-base babbitt. Steel is usually used for backing such bearings, which are generally used where loads are relatively light, not exceeding 1200 psi. The fatigue strength of this material is relatively low. The percentage of various ingredients varies with different manufacturers.

Loads up to 7000 psi can be accommodated by steel backed copper lined bearing with a coating of tin-base babbitt. Such babbitt is usually about .005 in. thick. If the babbitt fails, then the crankshaft can operate on the bronze without damaging the shaft. Solid aluminum bearings with an overlay of babbitt provide good corrosion resistance. Unit loads of up to 6000 psi may be carried. Another type of bearing is centrifugally cast solid bronze. Such bearings are frequently used for highly loaded piston pins and crosshead bushings. Steel back, silver lined bearings with a babbitt overlay, have had successful application on hardened shafts. The advantages of aluminum steel backed bearings include high fatigue resistance (taking loads up to 10,000 psi), corrosion resistance, good embeddability, and conformability.

Main bearing shells are held in position in the cylinder block by main bearing caps and cap bolts. Bearing caps support the crankshaft and consequently the loads of compression and combustion, as well as inertia of the connecting rods and pistons. These caps require very careful construction and are most commonly made from malleable alloy cast iron. In many cases, excessive bearing wear will result in low oil pressure reading.



C. FOUR-STROKE-CYCLE PRINCIPLE

Most of the Diesel engines used in underground coal mines develop power in a series of events known as the four-stroke-cycle. A cycle is one complete series of events that is constantly repeated. When the piston is at the top of the cylinder, called “top dead center” (TDC), and moves to the bottom of the cylinder, called “bottom dead center” (BDC), one stroke has occurred. Another stroke has occurred when the same piston travels from BDC to TDC.

In the top of the cylinder are holes that can be opened or closed as required. One is called the intake port, and the other is called the exhaust port. Their purpose is to allow fresh airflow into the cylinder and allow exhaust gases to escape as needed.

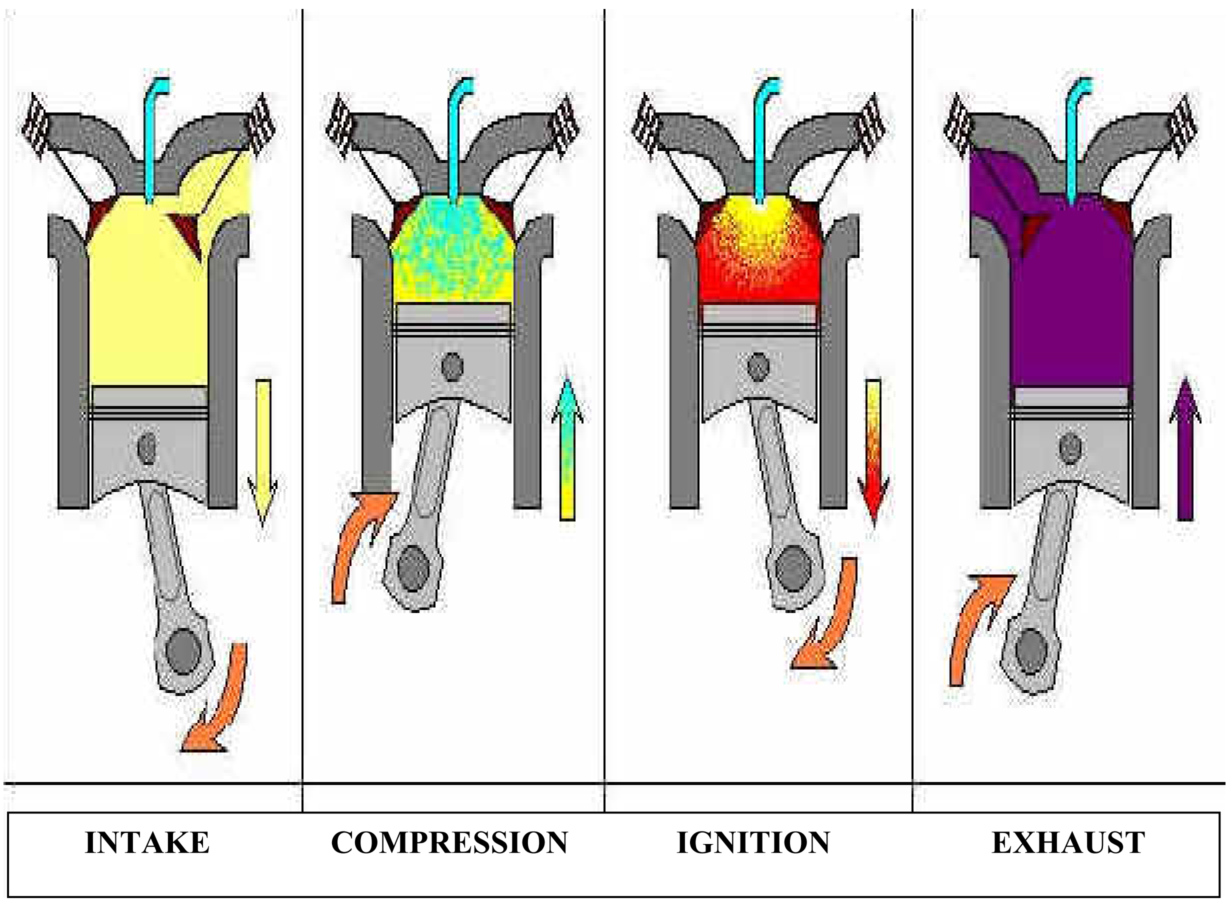
Intake Stroke: Starting with the piston at TDC, the piston is pulled downward by the connecting rod through the movement of the crankshaft. As the piston is pulled downward, two other actions happen simultaneously. First, the camshaft opens the intake valve. Second, air is drawn past the intake valve by the downward movement of the piston. The diesel engine draws in as much air as possible since there is no throttle restriction. When the piston reaches BDC, the intake stroke is completed.

Compression Stroke: The piston travels upward as the crankshaft continues to rotate. The camshaft has closed the intake valve, so the cylinder is sealed and the air is trapped. As the piston moves upward, the air becomes compressed and temperature increased to approximately 1000 degrees F. Just before TDC, the nozzle begins to spray fuel into the hot compressed air.

Power Stroke: The power stroke is sometimes called the expansion stroke. Fuel, injected in to the hot, highly compressed air, mixes with the air and burns rapidly. The combustion of the air-fuel mixture liberates the fuel’s heat energy, which causes a tremendous rise in heat and pressure in the combustion area. This heat and pressure provide the power to move the engine components, and the vehicle. The high pressure forces the piston, the only part of the cylinder area that can move, downward; and as the piston moves downward, the cylinder volume increases. This causes the pressure to decrease, and the burning gases to expand. As the burning gases expand, their temperature decreases.

Exhaust Stroke: The cylinder must be purged of the spent gases. The piston moves from BDC upward accomplishing this task. At the same time, the camshaft has opened the exhaust valve. This allows the piston to push the spent gases into the exhaust system. After the exhaust gases are pushed out, the exhaust valve closes. After the piston reaches TDC, the diesel cycle is repeated, starting with the intake stroke. Note that the flywheel has provided the necessary momentum (kinetic energy) to keep the engine turning during the intake, compression, and exhaust strokes.

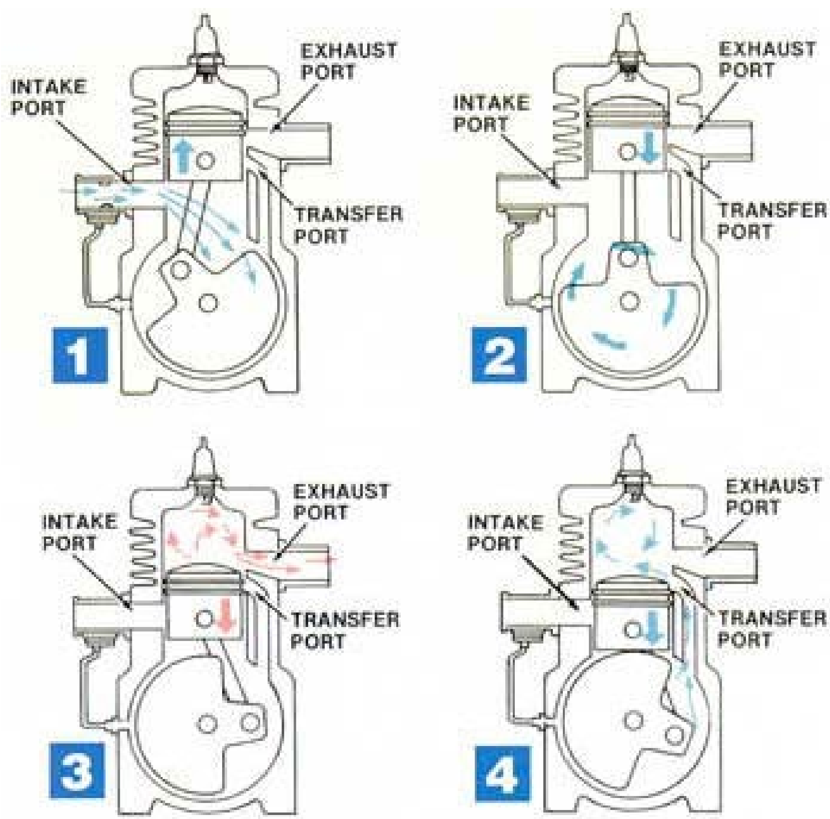
FOUR-STROKE-CYCLE



D. TWO-STROKE-CYCLE PRINCIPLE

The most important strokes of a diesel engine are the **compression** and **power**. **The intake and exhaust strokes are eliminated in a two-stroke diesel engine** by using a **turbocharger** or **supercharger** to do this pumping instead of using the engine's pistons.
The difference between a supercharger and turbocharger is the drive. The turbocharger uses the energy of the exhaust gases to drive itself, while the supercharger utilizes chains, gears, sprockets, or belts.

TWO-STROKE-CYCLE



E. VALVE TIMING

As previously stated, the diesel engine draws in a full charge of air on every intake stroke. How much of the cylinder fills with air is measured by a percentage called the volumetric efficiency. For example, if only 80% of available cylinder volume is filled with air at standard pressure, its volumetric efficiency is 80%. Volumetric efficiency is influenced by air pressure (density), air intake and exhausts restrictions, and velocity of the air and exhausts gases, the camshaft, and engine speed. The camshaft is designed to provide good power and economy. It does this by opening and closing the intake and exhaust valves at the proper time. This is called **valve timing**. The shape of the **lobes** on the camshaft determines valve timing.

Before discussing valve timing further, two other factors must be understood. First, as the piston travels through its stroke, its speed changes. Beginning at BDC, it has zero velocity, increases to a maximum velocity, and then decreases to zero velocity, and then decreases to zero velocity at TDC. There the piston stops and changes direction, increasing to maximum velocity, and decreasing to zero velocity BDC. When the piston is near either TDC or BDC, its speed and movement are minimal. The second factor is that air and exhaust gases do not move instantaneously. It takes time to get these gases moving. Once these gases are in motion, they continue to move by their own momentum and will eventually stop if no other force acts upon them. Valve timing must accommodate varying piston speeds and the different speeds of the intake air and exhaust gases.

Intake Valve Timing: The intake valve starts to open before TDC and closes after BDC. By opening the intake valve before TDC, fresh air can be drawn in early and the valve will be fully opened when the piston travels downward. The departing exhaust gases initially pull in the air, but as the piston approaches TDC, its speed and movement decrease. However, most of the exhaust gases in the exhaust manifold depart from the cylinder with great speed. This helps create a suction or low-pressure area behind the exhaust gases. Therefore, when the intake valve opens just before TDC, fresh air is drawn in by the suction created by departing exhaust gases. The incoming fresh air helps scavenge the cylinder of any remaining exhaust gases and gives the cylinder more time to draw in a fresh charge of air.

When the piston is moving downward on the intake stroke, air is drawn in. However, when the piston reaches BDC, its speed and movement are diminished.

The air, on the other hand, is still rushing into the cylinder because of the momentum imparted to it by the piston. Keeping the intake valve open just after BDC packs the incoming air into the cylinder.

Exhaust Valve Timing: To purge the cylinder of exhaust gases, the exhaust valve is timed to open before BDC and to close after TDC on the exhaust stroke. The opening of the exhaust valve just before BDC on the power stroke releases the remaining low pressure and ensures full exhaust valve opening by the time the piston does reach BDC. The remaining low pressure helps remove the exhaust gases and avoids putting pressure on the piston when it begins to travel upward. Thus, helping purge the cylinder and preventing backpressure regain what is lost in power by opening the exhaust valve early. Keeping the exhaust valve open after TDC helps scavenge the cylinder completely. The departing exhaust gases create a suction that helps pull in fresh air for the intake stroke. The time period in which both valves are open is called valve overlap.

F. HIGH COMPRESSION RATIO

There are **four main reasons** why a high compression ratio (CR) yields a high thermal efficiency:

1. **The higher the CR, the higher the expansion ratio.** The expansion ratio, like the CR is the comparison of cylinder volume from the time the piston is at BDC to when the piston is at TDC. But unlike the CR, the expansion ratio is the comparison of cylinder volume from the time the piston is at BDC to when the piston is at TDC. But unlike the CR, the expansion ratio is the amount the burning gases expand when the piston is traveling downward during the power stroke. When combustion initially occurs, the combustion chamber volume is very small. As the burning gases force the piston downward, the combustion chamber volume expands. During this expansion, the burning gases cool because the fuel's heat energy is converted to kinetic energy. Increasing the expansion ratio increases the amount of heat energy that is converted into kinetic energy because of greater expansion. If more heat energy is changed to kinetic energy, then less heat is ejected into the exhaust system, and less heat energy is wasted. This is the reason the exhaust system on a diesel engine does not get as hot as a gasoline engine's exhaust system
2. **A high CR helps mix the air with the fuel.** When the air is compressed, the air molecules are very active. This activity mixes more of the air molecules with the fuel molecules, causing more fuel to burn and release more heat energy.

3. **A high CR creates a small combustion space at TDC.** A small combustion space does not allow as much heat to escape through the combustion chamber wall. More heat is retained during the compression and power strokes. This enables igniting the fuel easier as well as improving thermal efficiency.
4. **The higher the CR, the smaller the volume when the piston is at TDC.** During the exhaust stroke, the piston pushes more of the spent gases out of the cylinder. This allows more fresh air into the cylinder, which provides better combustion.

The engine that can make use of high compression ratios has a better thermal efficiency. Because the diesel engine draws in only air, no ignition is possible until fuel is added. Therefore, the diesel engine compresses the air as much as possible to obtain maximum efficiency. The gasoline engine is limited because the fuel has been previously mixed with air and this mixture ignites if compressed too much, causing harmful detonation.

Limitations: There are limits on how much the air can be compressed in the diesel engine.

1. As the CR is increased, the gain in power becomes less and less. Finally, a point is reached when any increased CR does not result in any gain of power. This is due to the reduction in combustion volume in relation to piston movement being so small that any expansion in relation to piston movement is negligible. Therefore, the resultant power gain is negligible.

2. A high CR can reduce mechanical efficiency because of friction losses. When the CR is increased, the stress on the engine components becomes greater, and tighter seals are necessary. The bearing surfaces, pistons, crankshafts, connecting rods, and so on must all be strengthened to withstand the greater loads. The heavier parts decrease power output because of their weight and greater surface contact areas. These larger surfaces areas increase the amount of friction between parts. More power must be produced just to keep these parts moving while decreasing engine power output.

3. A high CR requires a heavy-duty starting system to overcome the high compression pressures and to rotate the heavier parts. The batteries must have enough power to start the motor. The starter motor must be of sufficient size to rotate the engine to approximately 100 RPM’s. This adds extra weight to the vehicle.

Most small, high-speed diesel engines have a CR of approximately 21:1 or higher. This is very high, even for a diesel engine. The reason is that the type of combustion chamber used, called indirect injection, has a large combustion surface wall area that can conduct more heat away. To overcome this, manufacturers have increased the CR. However, the CR is now so high that it contributes to increased friction losses, particularly at high engine speeds. At the upper end of the high-speed-car diesel engine RPM range, the fuel consumption almost equals that of comparable gasoline engines.

G. THE COMBUSTION PROCESS

Combustion takes place in the diesel engine when enough heat is available to ignite the correct proportions of air and fuel. Whenever the air and fuel are proportional, auto-ignition occurs. This means that combustion can start at more than one point, and the combustion rate is determined by the rate at which the air and fuel mix. This process is called **diffusion flame process**. The combustion process in the diesel engine is divided into three periods. The first period is called the **delay time** or **ignition lag** and begins near the end of the compression stroke. This occurs when the fuel is first injected into the cylinder until the fuel begins to burn. Time is needed to allow the fuel to vaporize and mix with the hot air. This period lasts about .001 second.

The second period is called the **rapid combustion** period. When the air fuel mixture is proportional and the temperature is high enough, auto-ignition occurs. The cylinder pressure rises suddenly when the first fuel is burned. This sudden rise in pressure is the familiar diesel knock you hear.

The third period is called the **controlled combustion period**. During this period, the nozzle is still providing fuel into the combustion chamber, but this rich core of fuel does not burn yet because it has not united with air. The already burning gases cause a tremendous turbulence, mixing the remaining air with the fuel. The cylinder pressure rate increase is slower than that of the previous period. It is during this period that the greater release of energy takes place. As the fuel and air are consumed, cylinder pressure and temperature decrease as cylinder volume increases.

The rate of combustion in the diesel engine is slower than in the gasoline engine. It must be slower to allow enough time for the fuel to mix with the air and burn in a controlled manner. As engine RPM increase, the amount of time available for combustion decreases. Because of the **slower rate of combustion**, the diesel engine cannot achieve the same high RPM as the gasoline engine.

The engine designer pays close attention to these periods of diesel engine combustion, because they affect engine performance. A long ignition delay time (approximately .002 second) will allow more fuel to enter the combustion chamber. When this fuel does burn (the rapid combustion stage), the sudden rise in pressure is too great, causing the knock to be much louder. Note: The loud knock is at the beginning of the combustion process. Any factor that increases the delay time increases the knock. The tendency to knock increases:

1. When the air and engine temperature is low. The engine has a harder time building up sufficient heat to ignite the fuel at the proper time. If ignition occurs later than designed, more fuel will enter the cylinder, causing the rise in pressure to be greater.

2. When poor mixing of the air with the fuel occurs. The nozzle not spraying fuel into the cylinder in the proper pattern causes this.

H. COMBUSTION CHAMBER

Although each engine component is important, the shape of the combustion chamber greatly determines the characteristics of the diesel engine. Regardless of the shape of the combustion chamber, this area must promote good combustion, limit emissions, limit noise, provide good fuel economy, and smooth operation.

The diesel engine combustion process is strongly influenced by air turbulence created by the shape of the combustion chamber area. The fuel injectors or injection nozzles spray the fuel into the combustion chamber in a pattern that takes advantage of the air turbulence, creating better mixing of the fuel with the air. Each combustion chamber shape creates its own unique air turbulence pattern that is right for some applications and wrong for others. It is important to know the difference designs, although at present, some are not found on passenger car diesel engines.

Combustion chambers can be divided into two basic groups, based on the point where fuel is injected. The two categories are **direct injectio**n (DI) and **indirect injection** (IDI). DI is used in large, slow-speed diesels, such as tractors and large trucks. Although DI is not used in small, high-speed diesels, it is important to know why and the advantages of this method.

Direct Injection: The DI method injects fuel directly into the combustion area above the piston. This method is often called the open combustion chamber, because the combustion chamber has direct access to the intake and exhaust valves. Getting the air to flow in the proper pattern within the combustion chamber is critical. The first step toward this goal involves how the air enters the cylinder at the intake valve. The shape of the intake passage directs the air in a manner that causes the air to swirl. The second step involves the shape of the piston. Piston shape creates further turbulence to promote a different pattern. Combustion causes even more turbulence. All this air turbulence has been created to ensure proper mixing of air with fuel for good combustion.

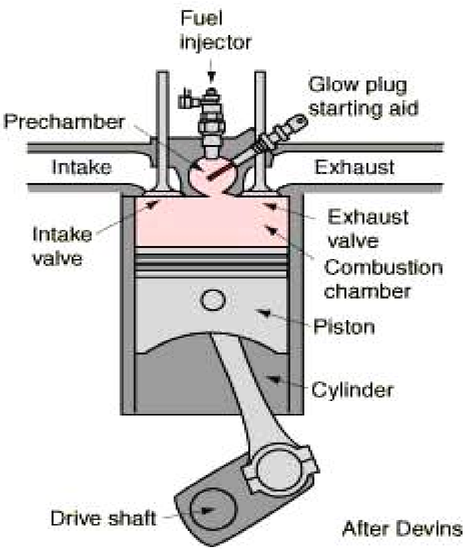
Characteristics of Direct Injection: The DI chamber has the highest fuel efficiency rating when compared to other designs. Its thermal efficiency is high primarily because there is little combustion surface wall area compared to combustion volume; therefore, little heat loss will occur. Lower compression ratios of approximately 15:1 to 18:1 can be used. Because of the low heat loss, a diesel engine with DI will start more easily and will not require extensive starting aids found in other types of combustion chambers. Finally, with DI the cylinder is easily purged of exhaust gases.

DI is not used in passenger car and small truck applications because it has a limited RPM range, up to approximately **2500 RPM**. The upper RPM limit is determined by the ability to take enough air into the cylinder and mix it properly with the fuel. Because the engine may not take in enough air at high RPM, the fuel will not mix properly; causing engine misfires that produce more hydrocarbons and particulates. When engine RPM increases, less time is available for the cylinder to take in air, and the **volumetric efficiency** decreases. The engine designer overcomes this by using larger valves, but with the use of DI, valves and nozzles are competing for the same space. Space is further limited by the relatively small cylinder bore diameter found in passenger car diesel engines. This again limits the amount of space that can be used by the valves.

Another characteristic of DI is that rapid combustion phase cylinder pressure rises at an extreme rate. Many car owners would consider the sharp knocking noise produced objectionable. For these reasons, DI is not found in applications requiring a high engine RPM. But, because the fuel efficiency is so good, engineers are working to improve this design. This will lead to an impressive mileage gain, about 10% to 15%, in fuel economy over today's diesel-powered cars.

Indirect injection: IDI injects fuel into an antechamber that is connected to a main chamber by a narrow passage. This design is also called the divided chamber. There are no intake or exhaust valves in the antechamber. Air is pushed through the narrow passage on the compression stroke and becomes turbulent within the antechamber. After the nozzle sprays fuel into the antechamber, combustion begins in this area. However, there is not enough air in the antechamber to complete the burning of fuel. The expanding burning gases force their way into the main chamber and intensely mix with the remaining air. This gives a fast, complete burning of the remaining rich air-fuel mixture.

There are variations of two basic IDI designs used in automobile and small truck applications: the **precombustion chamber** and the **swirl chamber**.



The Pre-combustion Chamber: The pre-combustion chamber is connected to the main chamber by a narrow passage. The precombustion chamber contains approximately 30% of the combustion volume when the piston is at TDC. Air is forced through the narrow passage and becomes turbulent. Fuel is injected and the burning gases force their way through the narrow passage. This narrow passage speeds up the expanding gases even more. The expanding gases mix with the air in the main chamber, rapidly completing the combustion process. There are variations on using this basic design.

The Swirl Chamber: This design is very similar to the precombustion chamber. However, the swirl chamber is spherical in shape and contains approximately 70% of the combustion volume. Air is forced through the narrow passage into the swirl chamber. Here the air swirls or becomes turbulent. Fuel is injected into the swirling air. Like the precombustion chamber, the burning mixture forces its way out the passage into the main chamber, where it completes the burning process. It should be noted that the swirl chamber and precombustion chamber are very much alike, and manufacturers have used both names to describe the same chamber.

Hybrid Chambers: Some designs incorporate features of the precombustion chamber and the swirl chamber. The shape of the combustion chamber strongly influences engine operation, noise, economy, and emissions. To meet these requirements, the engine designer uses certain features of each design. The result is a chamber that has characteristics of both the precombustion and swirl chamber.

Characteristics of Indirect Injection: The characteristics of IDI have made it the logical choice for diesel engines in passenger cars. IDI provides wide RPM range, low emissions, and low noise.

Wide RPM range: IDI allows the diesel engine to operate up to 5000 RPM. There are two reasons for this. First, mixing the air with the fuel is not as difficult when using a precombustion chamber or a swirl chamber. The air becomes turbulent easier in these smaller, confined areas. Second, the use of a precombustion chamber or swirl chamber allows the use of larger intake and exhaust valves. With these chambers, the nozzle is not located directly above the piston. Therefore, the nozzle is not competing with the intake and exhaust valves for the same space. The larger intake and exhaust valves improve the volumetric efficiency of the engine, particularly at higher RPM's when the engine has less time to breathe.

Low emissions: The first, complete burn provided by IDI produces very little hydrocarbons, carbon monoxide, and soot. The injected fuel combines with the air and changes mostly to carbon dioxide and water as a result of the burning process. Oxides of nitrogen (NOx) are produced when a high peak temperature is maintained. IDI has a lower peak temperature than DI. The lower temperature does not allow the oxygen and nitrogen molecules to combine easily and form NOx.

Low noise: IDI does not produce the extreme rise in pressure when the fuel is first burned. Because pressure does not rise at an extreme rate, and combustion begins in a relatively small area, the noise produced is diminished when compared to a diesel with DI.

Disadvantages of Indirect Injection: The disadvantages of IDI are that it provides less fuel economy and requires extremely high compression ratio. Fuel economy is lower with IDI because of higher heat loss, higher friction losses, small pumping loss of gases in and out of the antechamber, and prolonged and retarded energy release. The higher heat loss is the result of having a higher combustion surface wall area ratio to combustion volume. This conducts more heat away from the combustion area, reducing thermal efficiency. Because heat losses are higher, a higher compression ratio is needed to increase the temperature, particularly for engine starting and light load operation. When starting a diesel engine, a small amount of heat loss may prove the difference between a start and a no-start condition. Glow plugs are added to provide the additional heat when starting. Under light load operation, little heat is generated because little fuel is put into the cylinder. Having a high CR corrects these conditions, but the gain in thermal efficiency is very little. Furthermore, because a high CR is used, heavier parts and tighter seals are needed; therefore, friction losses are greater. This loss becomes greater as RPM's increase, because it takes more power to keep these parts moving and fuel economy decreases, particularly at high engine speeds. The narrow passage restricts the flow of gases in and out of the antechamber. This restriction creates a small loss in pumping efficiency and scavenging ability.

The energy release is retarded with IDI, producing a slow rise in pressure and heat, converting less heat energy to mechanical energy. However, this slow rise is what gives IDI its low-noise and low-NOx characteristics.

I. POWER AND SPEED CONTROL

Fuel Flow: Fuel stored in the fuel tank is drawn through the pickup unit by a fuel lift pump. Fuel travels through a water-in-fuel separator (optional) to the fuel supply (lift) pump. Then, it goes through a filter to the fuel injection pump. Excess fuel pumped by the fuel lift pump cools and lubricates the injection pump and nozzles. This fuel called return fuel is sent back to the fuel tank through the fuel return line. The fuel system also prevents air from entering the system, since air causes rough running.

Fuel Supply (Lift) Pumps: The fuel supply pump must draw an adequate amount of fuel from the tank and send it, under pressure, to the fuel injection pump. Fuel supply pumps pump more fuel than the engine can burn. The excess fuel is used for cooling and lubricating the injection pump and nozzles. The supply pump is located inside or outside of the fuel injection pump. We will address supply pumps that are mounted externally. Many fuel systems require an external fuel supply pump to draw the fuel out of the tank and send it, under low pressure, to the injection pump.

Mechanical supply pumps are either the plunger type or diaphragm type. The plunger-type supply pump is mounted on the injection pump housing. An eccentric on the injection pump camshaft actuates the plunger. As the plunger moves toward the camshaft, fuel is drawn in through the inlet (suction) check valve, filling the chamber above the plunger.

Fuel Filter: The purpose of any filter is to trap and prevent contaminants from reaching a critical amount. Particles larger than **10 microns** can damage the injection pump. In the diesel fuel system, the fuel filter prevents contaminants from reaching the finely machine, extremely close-tolerance fuel injection pump components. There may be one or two filters in the system other than the filter (strainer) in the fuel tank. If two filters are used, the first filter is called the **primary** filter. Its purpose is to trap large particles of dirt, 80 microns, and water. The next filter is the **secondary** filter. Its purpose it to trap the smaller particles missed by the primary filter. If only one filter is used, it is generally a two-stage design. The first stage, like the primary filter, traps larger particles of dirt and sediment. The second stage traps the smaller particles. Water will be trapped in the filter but will eventually be drained. Some filter housings are equipped with priming pumps that operate by hand. This aids in forcing fuel through the system and purging of air.

Fuel Injection Pump: The fuel injection pump performs several tasks. These include **metering the fuel, pressurizing the fuel, timing the fuel delivery, governing engine speed, and shutting off the engine**. Fuel injection pumps meter or control the amount of fuel that the cylinder receives. Varying the amount of fuel controls engine power and speed. The camshaft lobes are timed so that as the pump camshaft rotates, one-half engine speed, the tappet and plunger assembly is pushed upward. The plungers are actuated according to the engine-firing sequence. One pumping element is provided for each cylinder. An extra camshaft lobe is provided to actuate the fuel supply pump.

Fuel must be delivered to the nozzles under high pressure for the nozzles and engine to run smoothly. A pumping element is made of the components necessary to pressurize only the fuel. The arrangement and number of pumping elements vary according to need and the manufacturer. It is at the pumping element that low-pressure fuel is pressurized to as much as **6000 psi**. Pumping elements must be made with complete precision and quality materials to do the job properly.

Each pumping element consists of a **barrel and plunger**. The plunger has two distinct motions (1) reciprocating and (2) rotating. The plunger stroke is produced by the camshaft and always travels the same length; therefore, the plunger stroke is constant. The stroke generates the fuel pressure necessary for injection. At the bottom of the stroke, the plunger uncovers the fill ports, allowing fuel to enter under fuel supply pump pressure that fills the barrel. Fuel delivery to the nozzle and pressurization do not begin until the fill port is completely closed. The rising plunger continues delivery to the nozzle as long as the fill port is covered. This period is called the effective stroke.

When the rising plunger uncovers the fill port, pressure is relieved and no fuel is delivered to the nozzle. This ends the effective stroke. To meter the quantity of fuel delivered, the effective stroke must be variable. Since the lower control edge is slanted in relation to the upper control edge, rotating the plunger varies the distance over which the fill port is covered. The effective stroke depends on the distance from the upper control edge to the lower control edge. Thus, metering the quantity of fuel is made possible by the slant of the lower control edge and turning of the plunger, which vary the effective stroke. Although the plunger stroke will always be constant, turning the plunger can vary the effective stroke. As the plunger is turned, the distance over the fill port becomes greater and the effective stroke becomes longer. The amount of fuel injected into the cylinder increases as the effective stroke becomes longer.

At full engine load, the fill port is covered for the maximum effective stroke of the plunger, and the maximum amount of fuel is delivered to the nozzle. The control rack meshes with a gear on each plunger to provide the turning motion necessary to meter the amount of fuel delivered to the nozzles. Moving the control rack forward increases the quantity of fuel delivered, while moving it backward decreases the quantity of fuel delivered to the nozzles.

To shut down the engine, fuel above the plunger is not pressurized. A vertical groove on the side of the plunger is rotated, causing the groove to line up with the fill port. In this position, no fuel is pressurized; therefore, no fuel is sent to the nozzles, which shut off the engine.

Timing: Pressurized fuel delivery to the in-line pump begins with closing of the fill port. It also provides a point at which to set injection pump timing. By setting the engine crankshaft in a specified position, the injection pump is slightly rotated in the necessary direction until the pumping plunger closes off the fill port. This moment will be indicated by the almost complete cut-off of fuel flowing out of the No. 1 pumping element. This is the point when injection begins and is what must be adjusted.

Adjust injection pump timing by following these procedures:

1. Rotate crankshaft to specified position
2. Remove the fuel connection fitting from the No. 1 pumping element and install overflow pipe
3. Set control lever to maximum fuel position
4. Attach auxiliary fuel container to the point specified on the injection pump
    a. **NOTE:** Some manufacturers do not require the use of an auxiliary container but use the priming pump to supply fuel instead
5. Turn crankshaft slowly in the direction of engine rotation until fuel stops flowing from the overflow pipe
    a. **NOTE:** It is normal for a drop of fuel to form 10 to 15 seconds later

6. The crankshaft should be in the specified position. Rotate crankshaft two more turns. Fuel should stop flowing at the end of the second turn. If so, pump timing is set correctly
7. To adjust pump timing, loosen the mounting nuts and carefully rotate the pump in the appropriate direction. Fuel should not be flowing, and the crankshaft should be in the proper position
8. Remove the overflow pipe; and install the fuel connection fitting with a new gasket
9. Remove the auxiliary container
10. Check the control lever for freedom of movement
11. Bleed the fuel system. Run the engine and check for signs of leakage. Check idle speed

Governor: In-line injection pumps are equipped with a governor to limit both low and high engine speed. To maintain the desired speed under different engine loads, the amount of fuel must be metered to correspond to the required torque. In diesel engines, changing the amount of fuel injected does this. The control rack of the in-line injection pump must be moved to control the amount of fuel injected. In an automobile, the driver does this with the accelerator pedal between idling and maximum speed. However, the idling speed and maximum speed must be automatically limited so that the engine does not die during idle or exceed the maximum speed. The mechanical governor, which is driven by the diesel engine, is a speed-sensitive control.

The movement of the flyweights of the mechanical governor is transmitted to the control rack of the injection pump. The control rack is either moved into the STOP or MAXIMUM FUEL direction so that the engine speeds are automatically regulated within the desired ranges.

Maintenance: The maintenance of the injection pump, other than oil check level at regular intervals, should be performed by authorized dealers. Typical items performed in the field are pump removal and installation, idle adjustment, and pump timing.

Extreme caution must be exercised when working with injection pump, as this high pressure could be **<u>deadly</u>**.

J. INJECTION NOZZLE

Purpose of the nozzle: The injection nozzle is a component of the injection system that directs a metered quantity of fuel from the injection pump into the combustion chamber. The purpose of the injection nozzle is to direct the fuel into the combustion chamber in a manner that will provide optimum engine performance with a minimum of emissions. The injection nozzle accomplishes this purpose in two ways:

1. Atomizing the fuel
2. Spreading the fuel spray in a particular pattern

Atomization is the process of breaking down the fuel into very fine droplets. This process is necessary to mix the fuel with the compressed air, while forming a vapor. For the air to mix readily with the atomized fuel, the fuel is sprayed into the combustion chamber in a particular pattern. This is called **the spray pattern**. The spray pattern varies, depending on the shape of the combustion chamber and type of nozzle.

Basic parts of the injection nozzle: The injection nozzle is a component that can be divided into two parts: a nozzle holder and a nozzle. The nozzle holder supports the nozzle in the cylinder head. The nozzle is in the lower half of the injection nozzle, which contains the parts necessary to allow and prevent fuel flow. The nozzle is the component that directs fuel into the combustion chamber. It also contains a valve and a seat that prevents fuel from flowing when the valve is held against the seat. When the valve is pushed off its seat, the fuel can exit the nozzle. Note that some manufactures call the nozzle and holder a fuel injector. An injection nozzle receives fuel already under high (injection) pressure and does not boost pressure on its own.

Types of Nozzles: All nozzles presently used in diesel engines are differential pressure, hydraulically operated nozzles. This hydraulic action occurs when diesel fuel sent under high pressure by the injection pumps overcomes spring pressure. When this happens, the nozzle valve opens, allowing the fuel to exit the nozzle. When the fuel pressure drops, the **spring** closes and the nozzle valve, cutting off fuel flow.

Nozzles can be classified into two basic groups: **inward opening** and **outward opening**.

1. In the inward-opening nozzle, the nozzle valve moves up into the nozzle body

2. In the outward-opening nozzle, the nozzle valve moves out, away from the nozzle body. There are several variations of these two basic types of injection nozzles

Inward-opening nozzles: Hole-type nozzles contain holes in the top of the nozzle. The number and size of these holes dictate what shape the spray pattern will be for proper combustion. Pintle-type nozzles use a tapered valve that seats in a single orifice in the valve body. This produces a cone-shaped spray pattern.

Outward-opening nozzles: Poppet-type nozzles use a tapered valve that seats in a single orifice in the valve body. The poppet nozzle valve moves outward, producing a fine cone-shaped mist.

Nozzle testing: Nozzles are subjected to the intense heat and high pressure of the combustion chamber. Furthermore, they must provide a positive seal against any fuel leakage past the nozzle tip. Nozzles can operate for long periods of time without maintenance. However, contaminated fuel, misuse, and mechanical failure can reduce the nozzle's life expectancy. For this reason, nozzle servicing and testing is important.

Proper checking of a nozzle requires a nozzle tester: This tester can perform a series of tests on the nozzle. Three tests common to all nozzles are the opening pressure, spray pattern, and seat tightness tests. Opening pressure is the point where the nozzle begins to spray fuel: Spring pressure has a direct effect on opening pressure. Distorted or binding nozzle valves adversely affects opening pressure.

Spray pattern is the shape of the fuel as it exits the nozzle: Carbon and damaged nozzle tips are two common causes of a poor spray pattern.

Seat tightness tests for fuel leakage at the nozzle tip: A fuel droplet at the nozzle tip indicates a worn nozzle valve and seat. Two more tests performed on some nozzles are the chatter and return fuel tests. Chatter is the noise produced when the nozzle valve opens and closes rapidly. This noise indicates that the nozzle valve is moving freely in its bore. The return fuel test determines the amount of fuel that leaks past the nozzle valve and returns to the fuel tank. This test ensures that the nozzle is being adequately cooled and lubricated.

USE EXTREME CAUTION WHEN TESTING SPRAY NOZZLES

There are two precautions that must be strictly adhered to while using a nozzle tester.

1. **CAUTION**: Test Fuel Spray is Flammable. Keep vapor away from open flames and sparks

2. **CAUTION**: When testing nozzles, do not place your hands or arms near the tip of the nozzle. The high-pressure atomized fuel spray from the nozzle has sufficient penetrating power to puncture the skin and can destroy tissue, which may result in blood poisoning. The nozzle tip should be enclosed in a receptacle, preferable transparent, to contain the spray

II. Internal Combustion Sample Questions

Q. Excessive bearing wear in a diesel engine can cause:
A. Low oil pressure.

Q. A diesel engine converts:
A. Heat energy to kinetic energy.

Q. Precombustion chambers used on diesel engines help with:
A. Lowering exhaust emissions.

Q. Oil sludge, cylinder wear and piston ring wear can be caused by:
A. Excessive sulfur in diesel fuel.

Q. What determines the high fuel efficiency of a diesel engine?
A. Air fuel ratio, compression ratio, and heat value.

Q. Fuel ratio means:
A. Parts air to parts fuel ratio.

Q. The four strokes of a diesel engine are:
A. Intake, compression, power, and exhaust.

Q. Excessive sulfur in diesel fuel can cause:
A. Piston ring wear, cylinder wear, and oil sludge.

Q. The diesel engine exhaust valve controls:
A. The escape of burned gases.

Q. The camshaft of a diesel engine controls:
A. The intake and exhaust valves.

Q. What methods are used to cool compression ignition in diesel engines?
A. Water cooling and air cooling.

Q. Why are precombustion chambers used on diesel engines?
A. To lower emissions.

Q. What are some advantages of diesel engines?
A. Low fuel consumption, less fire hazard and low emission levels.

UNIT III
FUELS AND EMISSIONS

A. PETROLEUM

Diesel fuel, like gasoline, is made from petroleum. However, at the refinery, the petroleum is separated into three major components: gasoline, middle distillates, and all remaining substances. Diesel fuel comes from the **middle distillates** group, which has properties and characteristics different from gasoline. Each of these characteristics will be discussed and contrasted with gasoline.

B. HEAT ENERGY

Diesel fuel contains more **heat energy** than gasoline. The heat energy or value is commonly measured in **British Thermal Units** (BTU). One BTU is the amount of heat energy needed to raise the temperature of one pound of water one degree Fahrenheit. The diesel engine converts the fuel's heat into power. If the fuel used has high heat energy content, more heat energy will be released. Hence, if two engines are identical, each having the same thermal efficiency, but are fed two different fuels, the engine that receives the fuel containing the higher BTU content would be more economical. It would produce the same power using less fuel.

C. SPECIFIC GRAVITY

The **specific gravity** of a liquid is a measurement of the liquid's weight compared to water. Water is assigned a value of one. Diesel fuel is lighter than water but heavier than gasoline and can change if mixed with other fuels. The specific gravity of diesel fuel is important to engine operation. The fuel must be heavy enough to achieve adequate penetration into the combustion chamber. If the specific gravity is too low, all the fuel immediately burns upon entering the combustion chamber. This puts all the force of combustion on one small area of the piston instead of equal force across the dome. As a result, performance suffers, engine noise increases, and the pistons could eventually be damaged.

D. POUR POINT

Temperature affects diesel fuel more than it affects gasoline. This is because diesel fuels contain paraffin, a wax substance common among middle distillate fuels. As temperatures drop past a certain point, wax crystals begin to form in the fuel. The point where the wax crystals appear is the wax appearance point (WAP) or cloud point. WAP may change as a result of the origin of the crude oil and the quality of the fuel. The better the quality, the lower the WAP. As temperatures drop, the wax crystals grow larger and restrict the flow of fuel through the filters and lines. Eventually, the fuel, which may still be liquid, stops flowing because the crystals plug a filter or line. As the temperature continues to drop, the fuel reaches a point where it solidifies and no longer flows. This is called the **pour point**. In cold climates, it is recommended that a low temperature pour point fuel be used.

E. VISCOSITY

Viscosity is the property of a fluid that resists the force, which causes the fluid to flow **(resistance to flow**). Viscosity is measured by observing the time required for a certain volume of the fluid to flow, under stated conditions, through a short tube of small bore. A device called a viscometer measures the flow. The viscosity of diesel fuel directly affects the spray pattern of the fuel into the combustion chamber and the fuel system components. Fuel with a high viscosity produces large droplets that are hard to burn. Fuels with low viscosity sprays in a fine, easily burned mist. If the viscosity is too low, it does not adequately lubricate and cool the injection pump and nozzles.

F. VOLATILITY

Volatility is the ability of a liquid to **change into a vapor**. Gasoline is extremely volatile compared to diesel fuel. For instance, if diesel fuel and gasoline are exposed to the atmosphere at room temperature, the gasoline evaporates and the diesel fuel does not.

G. FLASH POINT

Flash point is the **lowest temperature at which the fuel burns when ignited by an external source.** The flash point has little bearing on engine performance but is important in fuel storage safety. The temperature at which the flash point occurs is regulated. If the flash point of diesel fuel is lower then specified, it would have the right combination of air and fumes that would ignite too easily, making the handling of it hazardous. Gasoline evaporates at a very low temperature, filling the tank with fumes that are potentially explosive.

H. CETANE RATING

The **ignition quality** of fuel refers to how well it self-ignites under heat and pressure. Diesel fuel's ignition quality is measured by the cetane rating. To get a **cetane number rating**, a fuel is compared to cetane, a colorless, liquid hydrocarbon that has excellent ignition qualities. Cetane is rated at **100**. The higher the cetane number, the shorter the ignition lag time (delay time) from the point the fuel enters the combustion chamber until it ignites. The exact rating is determined by mixing the cetane with a chemical called **methylnaphthalene**, which is rated at

zero since it does not ignite. The percentage of cetane mixed with methylnaphthalene that produces a similar ignition quality to the fuel being tested is the cetane number rating.

Ignition quality and flash point should not be confused. Flash point is the lowest temperature at which the fuel burns when ignited by an external source.

The quality of gasoline is measured by octane, which indicates the resistance of a fuel to self-ignite (knock). Premium gasoline has poor ignition quality, since it burns slower than regular gasoline and has more resistance to pre-ignition and detonation. The higher an octane number, the more resistance a fuel has to knocking. Diesel fuel cetane ratings are the opposite of gasoline octane ratings. For automotive diesels, the recommended cetane rating is approximate 45.

I. CARBON RESIDUE

When fuel is burned with excess air, carbon dioxide is formed. If the air (oxygen) is limited, carbon monoxide is formed. Carbon residue is the material left in the combustion chamber after burning. It is found not only in diesel engines, but also in other engines that burn hydrocarbon fuel.

The amount of carbon residue left by diesel fuel depends on the quality and the volatility of that fuel. Fuel that has a low volatility is much more prone to leaving carbon residue. The small, high-speed diesel engines found in automobiles require a high-quality fuel, since they cannot tolerate excessive carbon deposits. Large, low-speed industrial diesel engines are relatively unaffected by carbon deposits and can run on low-quality fuel.

J. SULFUR CONTENT

Sulfur content is common in fuels made from low-quality crude oil. Refining the oil removes only a portion of the sulfur. Sulfur increases ring and cylinder wear, causing the formation of varnish on the piston skirts and sludge in the oil pan. Changing the oil frequently or switching fuels often helps prevent wear. Fuels that have high sulfur content are often high in various nitrogen compounds. These nitrogen compounds, like sulfur, form corrosive chemicals causing excessive engine wear.

K. CONTAMINATION

Water Content: Water in diesel fuel is a major problem because water and diesel fuel readily mix. Careless storage and distribution of fuel invite problems. Diesel fuel that appears cloudy often contains water. Some of the problems that water causes are:

1. Corrosion of the fuel system. This can cause the fuel filter to plug with rust particles

2. Icing of the fuel system. Wherever the water collects and the temperature is low enough, ice forms, causing severe damage to the fuel system components

3. Inadequate lubrication of the injection pump and nozzles. Water does not have good lubricating qualities

4. Bacteria growth in diesel fuel

L. FUELS

Bacteria Content: Various fungi and bacteria attack diesel fuel. They ingest the diesel fuel as food, changing it to their waste products producing a slimy, gelatin-type growth. This growth not only plugs the fuel system but also produces an acid that is corrosive to fuel system components. Because the fuel may contain harmful organisms, any wound exposed to diesel fuel should be cleaned immediately. Fungicides and bactericides, which prevent their formation and growth, are available.

Commercial Fuel Ratings: There are three grades of diesel fuel for automotive use: 1-D, 2-D, and 4-D. At one time there was a grade 3-D, but it has been discontinued.

Grade 1-D is a kerosene-type fuel that has a lower viscosity, lower wax content, and lower BTU per gallon then 2-D. It is also more volatile than 2-D and usually has a higher cetane rating.

Grade 2-D is the fuel recommended for automotive and some industrial applications.

Grade 4-D is a fuel with a low cetane number. Low cetane number can result in abnormal combustion, loud engine knock and a long ignition lag time.

Blended Fuels: In cold climates it is often necessary to run on a blended fuel. A blended fuel reduces the WAP and pour point, allowing the fuel to flow at low temperatures. Typically, grade 1-D fuel is used to lower the WAP and pour point of grade 2-D fuel. Each manufacturer has specific instructions on what blend should be used at certain temperature. Usually, a 10% increase of grade 1-D to grade 2-D lowers the WAP by 2-degree Fahrenheit. However, since grade 1-D has lower heat energy content, **fuel economy and engine output power** also decrease.

Additives are chemicals added at the refinery to lower the WAP and pour point. At the refinery, the composition of the oil and wax content is known. The proper additives are blended with the fuel to give it the desired properties. Additives used in the aftermarket by owners and technicians may or may not work because of variations in oil composition. Furthermore, use of additives may violate the manufacturer's warranty. **CAUTION: Never blend gasoline with diesel fuel.**

Gasoline mixed with diesel fuel can create a powerful bomb. Diesel fuel alone in the tank emits very little vapor. Gasoline fills the tank with fumes that are too rich to burn. When mixed together, the combination of fuel vapor and air is potentially explosive. This mixture can be ignited in a variety of ways. A spark created by a static charge can occur merely by filling the tank. A person performing mechanical work on the vehicle can create a spark with tools or a lighted cigarette. Also, if the vehicle is in an accident, the fuel tank can explode.

M. FUEL STORAGE

Clean fuel for operating diesel engines is essential. Adequate containers are necessary to store fuel until it is used. Technicians who keep a small supply of diesel fuel on hand should be aware of a few facts:

1. Diesel fuel ages and will go stale. Keep a fresh supply available.

2. Variations in heat and humidity tend to create condensation in fuel storage containers. Fuel containers should be kept where the temperature is relatively moderate and out of direct sunlight.

3. Never store diesel fuel in galvanized containers. Diesel fuel causes the galvanized coating to flake off, contaminating the fuel system and clogging the fuel filters.

4. Containers should be properly labeled and identified as containing diesel fuel.

5. Never add alcohol to diesel fuel. This lowers the flash point of the fuel.

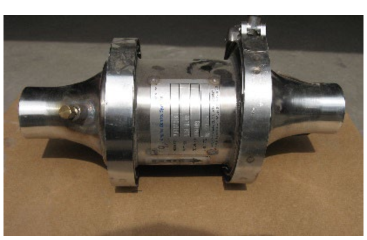
N. WATER SCRUBBERS

There are two types of water bath scrubbers, the **batch-type** where all the required water is contained within the scrubber tank, and the **water-makeup type** where the water level in the scrubber is maintained by a float valve fed from a separate tank. The scrubbers are characterized by high water consumption by virtue of their principle of operation. Energy, in the form of heat, from the exhaust gases is used to heat and evaporate water in the scrubber, thus reducing the heat of the exhaust gas. All of these devices are subject to one or more of the following problems: High water consumption and/or entrained water in the exhaust, excess entrained water in the form of steam effecting visibility, poor reliability of the makeup water float valve, inducing increased back pressure on the engine which degrades performance, and their large size affects vehicle design. Despite these shortcomings, diesel exhaust-gas water scrubbers have proven to be an effective device to cool exhaust gas and act as a flame trap. **In fact, state-of-the-art water scrubbers can capture 20-30% of the soot and up to 20% of the exhaust hydrocarbon.**

The float device connected to a reservoir, or in the case of batch-type scrubber, a low water level indicator, usually assures minimum water levels. Scrubbers are designed to maintain enough water throughout a specified period of operation (an 8-hour shift operating at a one-third load factor) to insure against any flame propagation caused from engine backfire or discharge of incandescent particles into a gassy atmosphere and to effectively cool the exhaust during daily operation. If a scrubber should fail to maintain the necessary water level while in operation (through material failure and subsequent loss of water, for example), built-in devices will detect the low water level and shut down the engine in a fail-safe manner.

Due to a variety of circumstances, it is not uncommon for these devices to be inoperable on mine equipment. Operational failure is defined as the condition of the water-scrubber being such that it will no longer function as it was intended because of a material or component breakdown. However, it is possible that the scrubber could perform the exhaust cooling and flame arresting functions but be weakened (by corrosion of example) to the point that it could not contain an explosion.

O. CATALYTIC CONVERTERS

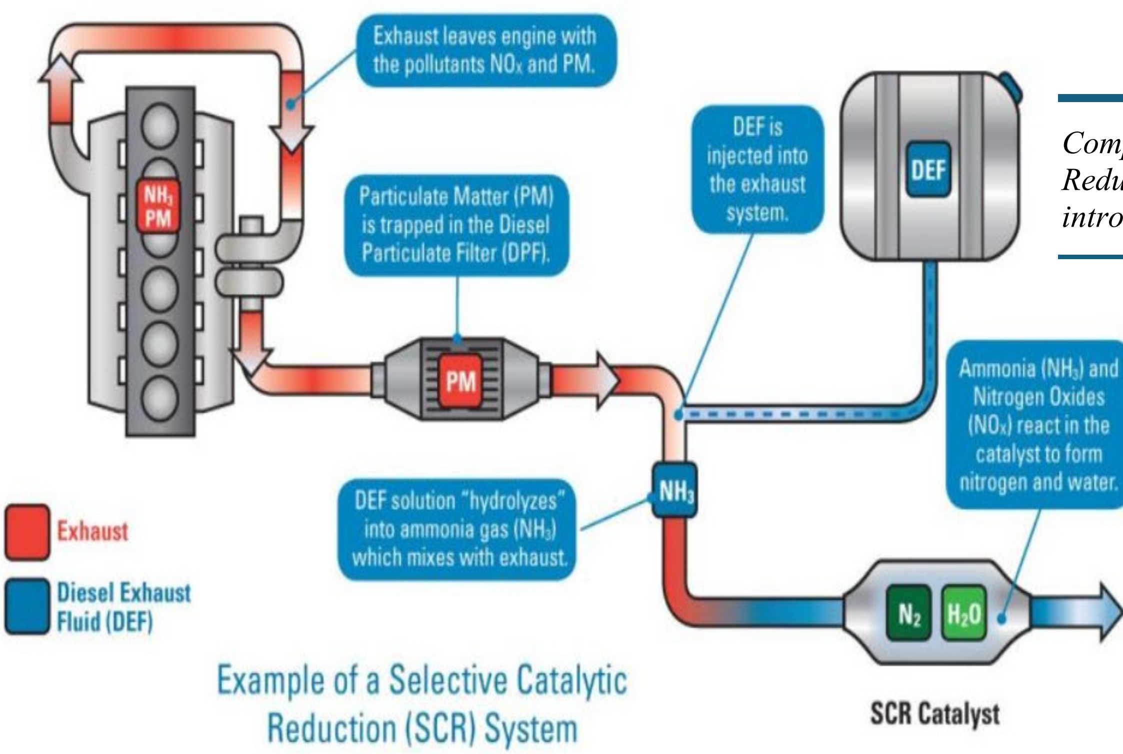


Oxidation catalytic converters, used on non-permissible equipment, oxidize some exhaust constituents and render them less toxic. The effectiveness of catalytic converters is dependent on their operating temperature, fuel quality, and catalyst formulation and configuration.

Positive effects of conventional catalysts are to reduce hydrocarbons (HC), carbon monoxide (CO), and aldehydes (associated with odor). **Catalytic**

converters, remove 60-80% of the hydrocarbons and 75-90% of the carbon monoxide. If an oxidation catalytic converter, a diesel particulate filter, or both, are installed on underground diesel-powered equipment, they shall be installed and maintained in accordance with manufacturer's specifications.

Basic Catalyzation



Complex SCR Catalytic Reduction with DEF Fluid introduced.

III. Fuel and Emissions Sample Questions

Q. What is flashpoint?
A. The lowest temperature at which fuel burns when ignited by an external source.

Q. What is ignition quality?
A. How well a fuel will self-ignite under heat and pressure.

Q. What is cetane?
A. Diesel fuel ignition quality rating.

Q. The injection system is:
A. The most important system of a diesel engine.

Q. 1D, 2D, and 4D represent:
A. Grades of diesel fuel for automotive use.

Q. Carbon residue is left:
A. In the combustion chamber after burning.

Q. Long ignition lag, uneven thrust on piston and cylinder, and loud engine knock are a result of:
A. Diesel fuel with a low cetane number.

Q. The sulfur content for diesel fuel used underground shall be:
A. In a concentration of 0.05 percent or less by weight.

Q. Carbon monoxide is formed when:
A. Diesel fuel is burned with a limited amount of air.

Q. Resistance to flow in diesel fuel is defined as:
A. Viscosity.

Q. What are the functions for a water scrubber?
A. Spark or flame arrestor and exhaust gas cooling.

Q. Catalytic converters, remove:
A. 60-80% of the hydrocarbons and 75-90% of the carbon monoxide.

UNIT IV
PREVENTIVE MAINTENANCE

A. PREVENTIVE MAINTENANCE

The objective of diesel engine maintenance is to keep engines in good operating condition to maximize productivity, engine life and reduce emissions. At best, a diesel engine is only approximately **32% efficient**. This means that only 32% of the combustion is useful output. Once equipment is put into operation, it is the responsibility of the mine operator to keep it in good condition. Preventive maintenance, periodic repairs, and adjustments are all part of a basic maintenance program. Maintenance can prolong or restore near-original efficiency of the engine.

B. AIR INTAKE SYSTEM

The high compression ratios and close tolerances of diesel engines require that airborne particles be removed from the large volumes of air consumed, in order to prevent abrasion of internal engine surfaces. This requirement demands a well-maintained air intake system.

Dust-laden mine air causes intake air filters to become filled with dust, creating a restriction that may exceed the manufacturer's recommended limit. Intake air filters should be replaced when the pressure drop across the filter exceeds the manufacturer's specification, usually 20 to 25 inches of water. A dirty intake filter, if not quickly replaced, will result in increased emissions and decreased performance. Loose clamps, small cracks in hose or piping, poorly connected slip joints, or defective seals must be repaired to keep out dirty air.

Installation of intake restriction indicators downstream of the air cleaner is recommended but the best method presently available for detection of these failures is a visual inspection of the air intake system. Installation should not compromise permissibility features on approved equipment. Equipment operators should carry spare filter elements for replacement when the gauge indicates a saturated filter. Used filter elements should be discarded. Not all air intake system failures can be detected by pressure drop indicators, e.g., a broken intake air duct or a punctured filter will not be detected.

Premature engine failures are often traced to dust intake. Dual element air filters and proper service intervals provide an excellent defense.

C. COOLING SYSTEM

The loss of engine cooling leads to scuffed cylinder walls and pistons, cracked heads, and burned valves. These conditions directly affect emission production and output power. A liquid-cooled engine relies on transfer of heat from the coolant to the radiator, and from the radiator to ambient air. Internal coolant passages of the engine and radiator must be kept free of mineral and rust deposits for effective heat transfer. Mine water is generally high in minerals and salts, rendering it unfit for use in engine cooling systems.

Ideally, a 50% mixture of distilled water and antifreeze should be used. Not only necessary for cold weather operations, antifreeze will prevent **rust** formation and also provide lubrication for the water pump. Antifreeze has a main ingredient called **Ethylene Glycol**. It has a boiling point higher than water and freezes at a lower temperature than water. Air-cooled engines reject heat via cooling fins, which are an integral part of the engine. During normal operation, these fins become coated with oil and dust, which bakes on to form an insulating layer. If this layer is allowed to build on the engine, overheating will result. Periodic steam or pressure cleaning will delay development of this condition. Whether the engine is air or liquid-cooled, the causes of overheating of diesels include the following:

1. Dirt deposits blocking airflow through the radiator or bent cooling fins, damaged fins and shrouds reduce airflow and contribute to overheating
2. Engine faults, such as retarded fuel injection timing and over fueling: These increase combustion and exhaust gas temperatures, putting additional heat load on the cooling system
3. Incorrect coolant solution: 50% antifreeze and distilled water solution is optimum: Also, internal scale and rust buildup caused by use of water with high mineral content reduces cooling system performance
4. Slipping fan and pump belts will reduce air and coolant flow
5. Engine temperature gage should be closely monitored to assure the regulation of heat flow by the thermostat
6. Liquid coolant level should be checked **daily**.
7. Radiator cap should be of proper pressure to ensure the maximum efficiency by raising the boiling point of the coolant.

D. FUEL QUALITY AND HANDLING

Number 2-D diesel fuel should be used whenever possible. Number 2-D possesses better **lubrication** properties and tends to extend fuel injection system component life. Additionally, 2-D has **higher energy** content per gallon than 1-D.

Sulfur content should be as low as possible. If the sulfur content is high, then the engine oil should be changed more frequently. The sulfur present in all diesel fuels directly affects the emissions of particulate sulfates and accelerates engine wear. Much of the sulfur will pass through the engine and reappear as SOx emissions. Sulfur in the fuel combines with moisture in the engine to produce sulfuric acid, which is corrosive to parts, bearings, and seals. Placing specifications on the purchase order should control the quality of fuel delivered to the mine.

Fuel contamination causes accelerated engine wear, because of extremely close tolerances, approximately .00008 in., of the injection equipment. Most fuels hold a small amount of sediment and abrasives in suspension that should be removed. Most engines include one or more filters to protect the injection system from dirty fuel. Filters are rated in microns. In addition to routine cleaning or replacement of filters, there should be periodic cleaning or draining of the vehicle fuel tanks. Proper fuel handling can reduce fuel contamination. It is important to minimize the number of fuel transfers and to store the fuel in tightly sealed containers that are clearly labeled.

Water is a common contaminant. It condenses in storage tanks, especially if the tanks are partially full and are at high humidity, or water may be in the delivered fuel. The best method to remove water is to install fuel-water separators on all equipment, minimize fuel transfer points, and keep fuel storage tanks full. There are three places where a fuel filter and water separator would be used in a good fuel handling system: (1) at the outlet of the surface storage tank, (2) at the pump side of the portable fuel trailers, and (3) on the engine.

E. FUEL INJECTION SYSTEM

The engine fuel flow rate is usually set at the factory or at an authorized service shop and is based on the MSHA horsepower and ventilation rating. Seals to discourage tampering are installed on the fuel pump because of the critical relationship between fuel-air ratio and emissions.

The function of the injection nozzles is critical to good fuel economy. Injectors act to mechanically atomize the liquid fuel by forcing it under very high pressure through small holes at a certain time. Whatever happens during operation to alter spray pattern, injection timing, or fuel charge, will alter engine performance and emissions. If the nozzles are dirty, improperly adjusted, or worn beyond tolerance, the engine will waste fuel. Very small particles of dirt in the fuel can damage the injectors. Carbon buildup on injector tips results in loss of power and requires more fuel to accomplish a given amount of work. Improperly adjusted nozzle opening pressures can affect the spray pattern, resulting in a poor fuel-air mixture and loss of fuel efficiency. Malfunctioning injectors cause smoking, uneven engine operation, and high CO and HC emissions.

If a fuel injector problem is the suspected cause of excessive smoke, the following items should be inspected: fuel injector and nozzles for leakage, opening pressure, nozzle valve sticking, spray pattern, and correct nozzle part number. To check injectors, they must be removed and placed in a special test fixture. A simple apparatus can be used to check spray pattern and nozzle opening pressure. Specially trained technicians who can flow-balance and match injector delivery rate, and check spray patterns should use more sophisticated bench-test equipment. It is advisable to inspect injectors on a routine basis, as specified in the engine manual.

Unless manually adjusted, diesel injection timing generally remains constant over long service intervals. Timing could be improperly adjusted at the factory or by a serviceperson, or otherwise altered to yield higher output horsepower. Engine manufacturers usually allow a 1-degree deviation from the recommended setting. Induced fault testing has shown that injection timing (advanced or retarded) will affect all emissions. CO will increase whether timing is advanced or retarded from the factory setting, particles will tend to decrease slightly with retarded timing and increase with advanced timing, and NOx increases when timing is advanced and decreases when it’s retarded. Once properly set, fuel injection timing does not require frequent adjustment.

F. LUBRICATION SYSTEM

Failure of the lubrication system usually results in catastrophic engine failure. System failures are often caused by a component failure, such as seized bearings, lubricant breakdown, contamination, or engine overheating. To control these failures, it is important to keep the crankcase lubricant at the recommended level, free of solid and liquid contamination, and maintain the engine’s cooling system. If an engine becomes excessively hot, the oil viscosity is lowered and oil consumption increases, resulting in accelerated engine wear.

G. EXHAUST SYSTEM

Excessive exhaust gas restriction or **backpressure** can result from a partially plugged water scrubber, flame trap, catalytic converter, or dented exhaust pipe. Excessive backpressure causes increased emission of some pollutants and decreased power output.

The most commonly reported scrubber service problems are caused by sludge and mineral deposit buildups around internal baffles and water passages. Particulate matter introduced into the water scrubber form the exhaust gases and other sources can coagulate to form a heavy sludge. High concentrations of suspended solids in the available water of underground mines are very common. If not removed, these contaminants can restrict the water flow from the makeup tank and through other internal passages. High concentrations of dissolved solids in the scrubber solution, primarily calcium salts, can lead to mineral deposit buildups on internal surfaces, which can lead to further plugging. The severity of both these problems can be reduced if maintenance personnel adhere to rigid scrubber flushing and cleaning schedules. Since the likelihood of this problem increases with the solution residence time, manufacturers usually recommend that water scrubbers be flushed and thoroughly cleaned each day. Household and laundry detergents have been reported to be often used as cleaning agents.

H. RECOMMENDATIONS

1. **Good housekeeping should be practiced around diesel equipment.** Cleanliness and orderly storage of all parts, tools, and oils helps provide an efficient and safe location to work

2. **Follow any legal requirements, which are applicable to the maintenance of diesel equipment**

3. **Be abreast of the procedure in which the safety system** shut down operates. This will help decrease repair time when a problem occurs.

4. **Read operation and maintenance manuals.** The operator’s manuals should be made required reading to learn the correct operation and maintenance of the vehicle and engine. The engine manual should be followed for service intervals and other vital information. Manufacturers have developed engines to be a balance between performance, durability,

and emissions. **Deviation from proper servicing methods and intervals will result in degraded performance and emissions, and reduced engine life.**

5. **Use low sulfur fuel**. It is especially important to limit the amount of sulfur in the fuel. Low sulfur content is important for maximum engine life, lubrication, and fuel economy. Also, limiting the amount of sulfur in the fuel controls sulfate emissions.

6. **Keep it clean.** Dirt is very detrimental to engines. Regular checks and maintenance of the machine's air induction system are necessary to peak engine performance. The diesel consumes large volumes of air to function. If the volume of air is restricted or insufficient, the engine will perform poorly and emit large quantities of particulates and other pollutants, which indicate that the fuel is not burning completely. One of the most common causes of excessive and dark smoke is intake air restriction caused by plugged air cleaners. The most effective way to improve engine life is to frequently and correctly service the air cleaner.

7. **Keep it cool.** Engine overheating is a frequent cause of premature engine failure. Ensure that lubrication oil is the correct viscosity and kept at the recommended level. Keep all heat exchangers free of accumulated dirt and open to circulating air.

8. **No extended idling.** An established tradition of diesel engine operation is idling engines for long period, which wastes fuel. Fuel consumption is not the only problem; engines at idle tend to overcool with operating temperatures well below ranges recommended by the manufacturers. This results in incomplete combustion, which leads to **varnish and sludge formation**. Unburned fuel washing down cylinder walls removes the protective film or lubricant and results in accelerated wear. Once fuel mixes with crankcase oil, dilution further reduces effectiveness of the lubricant. Planning for cold starts and shut down of engines for work breaks is now regarded as much more economical and less damaging to engines than prolonged idling. Engines should be shut down if idle periods are expected to exceed five minutes.

9. **Beware of black smoke.** Dark smoke from a diesel engine exhaust is a result of an improper fuel-air ratio. This is a dangerous condition because of high CO and particles in the exhaust. Equipment emitting black smoke should be shut down and taken to a maintenance area for diagnosis and

repair. Black smoke may indicate incorrect governor setting, air cleaner restrictions, incorrect fuel delivery, improper injection pump timing or cam valve timing, defective injectors or nozzles, poor compression, or incorrect timing advances.

POSSIBLE EXHAUST COLOR INDICATION

Black smoke is the most common type of smoke that is emitted. Black smoke is from fuel left unburnt during the combustion event.
The potential causes include fuel injectors sticking, poor turbo performance, EGR valve or EGR cooler issues, and **dirty air cleaners** causing heavy restriction.

Blue smoke suggests an **oil related issue** where oil is going through the combustion chamber. Several issues can cause blue smoke, however, the most common ones would be worn valve guides, valve seals or piston rings/cylinder seal being broken. Even changes like the type or grade of oil can potentially cause this so if you have made a change paying extra attention afterwards would be a good idea.

White smoke can be caused by numerous things, but the most common would be **raw unburnt diesel** passing into the exhaust. This typically occurs with severely defective injectors, poor cylinder compression or even an issue with injection timing.
Another reason you may see white smoke exiting your tailpipe is **coolant** making its way into your cylinder. This can pass through into the exhaust stream and wreak havoc on your aftertreatment components.

IV. Preventive Maintenance Sample Questions

Q. Antifreeze should be used in the summer to assist with cooling and:
A. Inhibit rust.

Q. A diesel engine converts:
A. Heat energy to kinetic energy.

Q. The radiator is the heat exchanger on:
A. Water cooled diesel engine.

Q. If the exhaust system is removed from a diesel engine, then:
A. The engine should be removed from service until the exhaust can be replaced.

Q. Fire protection systems shall be maintained according to the:
A. Manufacturer's recommendations.

Q. Fuel filters are rated in:
A. Microns.

Q. A certified diesel engine mechanic shall:
A. Perform maintenance on the intake system of a diesel engine.

Q. A dirty intake air filter can cause:
A. Diesel engine overheating and black smoke.

Q. Water from the air tank should be:
A. Drained at least daily.

Q. Oil is used to reduce:
A. Friction.

Q. Improper fuel-air ratio will cause:
A. Black smoke, high CO and particles in the exhaust.

Q. Deviation from proper servicing methods will result in:
A. Degrading performance, higher emissions, and reduced engine life.

UNIT V
VIRGINIA DIESEL REGULATIONS

Regulations Governing the Use of Diesel-Powered Equipment in Underground Coal Mines

A. Definitions (4 VAC 25-90-10)

The following words and terms when used in this chapter shall have the following meanings unless the context clearly indicates otherwise:

- **Chief:** the Chief of the Coal Mine Safety of the Virginia Department of Energy.
- **Division**: the Coal Mine Safety of the Virginia Department of Energy.
- **MSHA**: the Mine Safety and Health Administration.
- **TLV** (Threshold Limit Value): the airborne concentration of a substance that represents conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse effect as recommended by the American Conference of Government Industrial Hygienists.

B. Diesel equipment approval (4 VAC 25-90-20)

1. Diesel-powered equipment shall not be permitted underground without receiving approval from the Chief or his designated representative. Approval will be based on:

a. Meeting the requirements of this regulation.

b. Compliance with 30 CFR Part 7 Subpart E, design and performance requirements for non-permissible diesel-powered equipment.

Compliance with 30 CFR Part 7 Subparts E and F, and 30 CFR Part 36, requirements for permissible diesel-powered equipment.

c. An evaluation by the Coal Mine Safety of the equipment, undiluted exhausts emissions, the adequacy of ventilation, and fire protection.

d. If an oxidation catalytic converter, a diesel particulate filter, or both are installed on underground diesel-powered equipment they shall be installed and maintained in accordance with manufacturer's specifications.

2. If at any time the Chief determines that any condition or practice permitted under this approval may threaten the health or safety of employees, additional requirements may be imposed for the purpose of eliminating the condition or practice.

3. Stationary diesel-powered equipment, portable diesel generators, diesel powered ambulances, and diesel firefighting equipment shall not be permitted underground without an approved plan. The plan shall address ventilation, fire protection, fuel handling, storage, and any other requirements the Chief determines as necessary to protect the health and safety of miners.

4. The Coal Mine Safety shall be notified after completion of any alterations in design, substitution of components, and any other changes in the condition of operating diesel-powered equipment that affects emissions. Additional engine testing and adjustments shall be required as necessary should any resulting changes be made that may increase diesel emissions.

C. <u>Operation of diesel equipment (4 VAC 25-90-30</u>)

1. All mobile underground diesel-powered equipment shall be operated safely and shall meet the following requirements:

a. Be free of excess accumulation of coal dust, oil, grease, fuel, and other combustible materials

b. Be operated with:

1. An audible warning device
2. An engine start and stop mechanism
3. Guards over moving components
4. A proper lifting device for the re-railing of such equipment
5. Sanding devices, expect for personnel carriers that transport

not more than five personnel (self-propelled rail equipment only)

6. Headlights on each end
7. Park and service brakes
8. A fire suppression system
9. Intake and exhaust systems in good condition
10. A self-closing filler cap on the fuel tank

To avoid contact with energized trolley wires or trolley feeder wires a six-inch minimum clearance shall be maintained or the equipment shall be adequately insulated.

2. All mobile diesel-powered equipment operated in or inby the last open crosscut or in return air courses shall be permissible. Such diesel-powered equipment shall be maintained and operated in accordance with 4 VAC 25-90-20 and as follows:

   a. Electrical component permissibility shall be maintained

   b. Emergency engine shutdown shall be operable

   c. Flame arrestors (intake and exhaust) shall be provided

   d. Low-level shutdown (water bath/scrubber) shall be operable

3. The engine of mobile diesel-powered equipment shall not be left idling unattended.

4. The engine of any mobile diesel-powered equipment shall not be capable of starting unless the transmission controls are in the neutral position.

5. The operation of any diesel-powered equipment in any manner or under any condition that does not comply with the requirements of this chapter shall result in a notice of violation and if not corrected within a reasonable time, a closure order shall be issued that requires the machine be taken out of service until such condition or practice is corrected. Upon review of the history of violations, the Chief may void the approval for use of underground diesel-powered equipment at that mine.

D. Maintenance of diesel equipment (4 VAC 25-90-40)

1. Engine intake and exhaust systems shall be inspected visually by an authorized person at least once each day that the equipment is operated.

2. Permissible and emission components of diesel-powered equipment shall be inspected weekly by a certified diesel engine mechanic in accordance with the instructions of the manufacturer and all applicable federal and state requirements.

3. All filters on diesel engines shall be maintained or replaced as recommended by the manufacturer or more often if necessary.

4. Maintenance and repair work on emission components shall be done by a certified diesel engine mechanic in accordance with the instructions of the manufacturer and all applicable federal and state requirements.

5. All diesel-powered equipment shall be equipped with an hour meter to accurately display engine run time.

6. Maintenance manuals shall be made available for review by interested persons.

7. Records shall be kept of inspections, maintenance, and repair work for at least one year and shall be made available for inspection by interested persons.

E. Ventilation of diesel equipment (4 VAC 25-90-50)

1. The ventilating air in all active areas where diesel-powered equipment is operated shall not have combustible or other contaminating gases in such concentration that may affect combustion in the diesel engine by materially increasing toxic, poisonous or other objectionable constituents in the engine exhaust.

2. The air supplied for ventilation where diesel-powered equipment is used shall contain less than 1.0% by volume of methane.

3. The minimum ventilating air quantity maintained in the last open crosscut of each working section where units of diesel-powered equipment are operated must be at least the sum of that specified on the approval plates of all the diesel-powered equipment to be operated in these areas.

4. The minimum ventilating air quantity maintained in the intake reaching the working face of each longwall and at the intake end of any pillar line where units of diesel-powered equipment are operated on the working section must be at least the sum of that specified on the approval plates of all the diesel-powered equipment to be operated in these areas.

5. The minimum ventilating air quantity for an individual unit of diesel-powered equipment being operated outby the working section shall be at least that specified on the approval plate for that equipment. Such air quantity shall be maintained:

a. In any entry where the equipment is being operated in areas of the mine developed on or after July 18, 2001

b. In any air course with single or multiple entries where the equipment is being operated in areas of the mine developed prior to July 18, 2001

c. At any other location as the Chief may require

6. The quantity of ventilating air supplied to the active areas where diesel powered equipment is operated must be adequate to dilute and carry away constituents of the engine exhaust so that the composition of the air meets the air quality standards set forth in 4 VAC 25-90-70.

F. Emission testing and evaluation (4 VAC 25-90-60)

Undiluted exhaust emissions of diesel engines, to include each side of a dual exhaust system, on diesel-powered equipment used in underground coal mines shall be tested and evaluated weekly by an authorized person. The mine operator shall develop and implement effective written procedures for such testing and evaluation that shall include the following:

1. The method for which a repeatable load test is conducted that must include an engine RPM reading.

2. Sampling and analytical methods used to measure diesel engine emission concentrations.

3. Instrumentation (and calibration of instrumentation) capable of accurately detecting carbon monoxide in the expected concentrations.

4. The method of evaluation and interpretation of sampling results.

5. The concentration or changes in concentration of carbon monoxide that will indicate a change in engine performance and an action plan to address changes in performance. The operator will establish a baseline level of diesel exhaust emissions, subject to approval by the Chief, based upon the MSHA engine approval data and the average of the first four undiluted exhaust emission tests required by this section. **This plan will establish an action level not to exceed the lesser of two times the baseline or 2500 parts per million (ppm) of carbon monoxide.** Should the action level be exceeded, the machine shall be removed from service and engine performance improved.

6. The maintenance of records necessary to track engine performance. These records shall be:

   a. Recorded in a secure book that is not susceptible alteration, or recorded electronically in a computer system that is secure and not susceptible to alteration
   b. Retained at a surface location at the mine for at least one year and made available for inspection by interested persons.

G. <u>Air Quality (4 VAC 25-90-70)</u>

1. During on-shift examinations required by Section 45.2-827 of the Code of Virginia, a mine foreman authorized by the operator shall determine the concentration of carbon monoxide (CO) and nitrogen dioxide (NO_2):

   a. In the return of each working section where diesel equipment is used inby the loading point at a location which represents the contribution of all diesel equipment on such section.

   b. At a point inby the last piece of diesel equipment on a longwall or shortwall when mining equipment is being installed or removed. This examination shall be made at a time, which represents the contribution of all diesel equipment used for this activity including the diesel equipment used to transport longwall or shortwall equipment to and from the section.

   c. In any other area designated by the Chief where diesel equipment is operated in a manner, which can result in significant concentrations of diesel, exhaust emissions.

d. The concentrations of carbon monoxide (CO) and nitrogen dioxide (NO_2) shall not exceed the following threshold limit values:

Threshold Limit Values (TLV)	
Carbon Monoxide (CO)	25 ppm
Nitrogen Dioxide (NO_2)	3 ppm

2. Samples of CO and NO_2 shall be collected and analyzed:

a. By appropriate instrumentation which has been maintained and calibrated in accordance with the manufacturer's recommendations.

b. In a manner that makes the results available immediately to the person collecting the samples

c. During periods that are representative of conditions during normal operations.

3. The results of these tests shall be:

a. Recorded in a secure book that is not susceptible to alteration, or recorded electronically in a computer system that is secure and not subject to alteration

b. Retained at a surface location at the mine for at least one year and made available for inspection by interested persons.

H. <u>Fire protection for diesel-powered equipment. (4 VAC 25-90-80)</u>

1. Mobile, diesel-powered equipment shall have a multipurpose dry chemical type (ABC) fire suppression system or equivalent approved system.

2. Nozzles and reservoirs shall be placed in accordance with the manufacturer's specifications to provide maximum protection to the fuel tank compartment, motor compartment, battery compartment and hydraulic tanks.

3. Stationary diesel-powered equipment must be equipped with an automatic multipurpose dry chemical type (ABC) or equivalent approved fire suppression system.

I. Fuel specifications. (4 VAC 25-90-90)

1. The fuel for diesel-powered equipment approved for service in underground mines shall be low volatile hydrocarbon fuel with a flash point of 100° F or greater at standard temperature and pressure and shall contain sulfur in a concentration of .05 % or less by weight.

2. The mine operator shall maintain on the mine site and make available for inspection a statement from the diesel fuel supplier certifying the sulfur content and flash point of the diesel fuel to be used underground. This statement shall be up-dated annually and whenever the fuel distributor is changed.

J. Fuel use, storage, and handling. (4 VAC 25-90-100)

1. Unless otherwise approved, fuel taken underground shall be transported in metal containers that have self-closing devices.

2. Fuel taken underground and awaiting transfer to diesel-powered equipment fuel tanks shall be stored in a closed compartment or container constructed of incombustible material and shall be kept in a well-ventilated location until placed in the fuel tank.

3. Fuel shall be transferred from the storage compartment to a fuel tank through a flexible hose that is fitted with a self-closing valve. This does not apply to portable containers of five gallons or less.

4. The fuel handling system and the diesel-powered equipment shall be frame grounded so that a difference in potential does not exist when fuel is being transferred from the storage compartment to the fuel tank. This does not apply to portable containers of five gallons or less.

5. The air vents on fuel handling equipment shall be flameproof. This does not apply to portable containers of five gallons or less.

6. When fuel is being transferred from a storage compartment to the diesel equipment fuel tank, the engine shall be stopped.

7. A supply of sand or other suitable incombustible material for absorbing spilled fuel shall be available during the transfer of fuel from a storage compartment to the diesel equipment fuel tank. Fuel spilled shall be cleaned

up immediately.

8. In order to prevent unintentional opening all drain plugs in the fuel handling system shall be threaded, sealed, locked, and protected in the closed position.

9. During fuel handling operations, precautions shall be taken to keep the fuel clean and free from contamination by foreign material such as dirt, sediment and water.

10. Diesel fuel storage and handling in a working section shall comply with the following:

a. Underground storage areas that exceed 100 gallons shall be vented with intake air that is coursed into a return air course or to the surface and not used to ventilate working places.

b. At least one 20-pound approved ABC type fire extinguisher and no less than 200 pounds of rock dust per 100 gallons of fuel storage shall be maintained at the designated underground mine storage area.

c. Only one temporary underground diesel fuel storage area is permitted for each working section or in each area of the mine where equipment is being installed or removed. Temporary storage areas must be located within 500 feet of the current loading point, the projected loading point where equipment is being installed, or the last loading point where equipment is being removed.

11. Temporary and permanent underground diesel fuel storage facilities must be:

a. At least 100 feet from shafts, slopes, shops, or explosive magazines

b. At least 25 feet from trolley wires, power cables, or electrical equipment not necessary for the operation of the storage facilities or areas

c. In a location protected from hazards of other mobile equipment

Storage underground shall be limited to a typical 48-hour supply not to exceed 1,000 gallons.

V. Virginia Rules and Regulations Sample Questions

Q. When 100 gallons of diesel fuel are stored underground, then:
A. One twenty-pound fire extinguisher and no less than two hundred pounds of rock dust must be available.

Q. Diesel fuel spilled underground shall be cleaned up:
A. Immediately using sand or other suitable noncombustible material for absorbing.

Q. Diesel fuel storage facilities located underground shall be limited to a:
A. 48-hour supply not to exceed 1,000 gallons.

Q. The Chief of the Coal Mine Safety must give written approval before:
A. Diesel powered equipment is permitted underground.

Q. Prior to taking underground, all diesel-powered equipment shall meet the requirements of:
A. The Virginia Mine Laws and Regulations and MSHA requirements.

Q. Engine intake and exhaust systems shall be visually inspected:
A. At least once a day

Q. On working sections where diesel equipment is used:
A. Once each shift in the return tests should be conducted for carbon monoxide and nitrogen dioxide.

Q. A working section can have:
A. Only one temporary diesel fuel storage center.

Q. Diesel fuel taken underground shall be transported:
A. Metal containers with self closing devices

Q. A Diesel Engine Mechanic must:
A. Attend 4 hours of training each year.

Q. All diesel-powered equipment used in the return airways must be:
A. Permissible and maintained permissible.

Emissions Testing Sample Questions

Q. What is the required air quantity where diesel equipment is operated?
A. Air quantity must be adequate to dilute and carry away constituents of the engine exhaust.

Q. The quality of air where diesels are operated must dilute:
A. Carbon monoxide to less than 25 ppm and nitrogen dioxide to less than 3 ppm.

Q. During on-shift examinations, when diesel equipment is used on an active section, what tests shall be conducted?
A. Carbon monoxide and nitrogen dioxide shall be collected during normal section operating conditions.

Q. What is the action level for undiluted exhaust?
A. Two times the established baseline or 2500 ppm CO, which ever is less.

Q. Emissions will increase if:
A. The air intake system is restricted.

Q. What i the maximum threshold limit value allowed in the return of each working section for CO and NO2?
A. CO = 25 PPM NO2 = 3 PPM

Q. If undiluted exhaust is out of compliance, then:
A. Diesel equipment shall be taken out of service until emissions are improved.

UNIT VI

30 (CFR)-CODE OF FEDERAL REGULATIONS
UNDERGROUND DIESEL REGULATIONS

30CFR PART 7 TESTING BY APPLICANT OR THIRD PARTY

SUBPART E – Diesel Engines Intended for Use in Underground Coal Mines

§7.81 Purpose and effective date

Subpart A general provisions of this part apply to this subpart E. Subpart E establishes the specific engine performance and exhaust emission requirements for MSHA approval of diesel engines for use in areas of underground coal mines where permissible electric equipment is required and areas where non-permissible electric equipment is allowed. It is effective November 25, 1996.

§7.82 Definitions

1. **Category A engines:** Diesel engines intended for use in areas of underground coal mines where permissible electric equipment is required.

2. **Category B engines:** Diesel engines intended for use in areas of underground coal mines where non-permissible electric equipment is allowed.

§7.84 Technical requirements

1. **Fuel injection adjustment:** The fuel injection system of the engine shall be constructed so that the quantity of fuel injected can be controlled at a desired maximum value. This adjustment shall be changeable only after breaking a seal or by altering the design.

2. **Maximum fuel-air ratio:** At the maximum fuel-air ratio determined by §7.87 of this part, the concentrations (by volume, dry basis) of carbon monoxide (CO) and oxides of nitrogen (NOx) in the undiluted exhaust gas shall not exceed the following:
   a. There shall be no more than 0.30 percent CO and no more than 0.20 percent NOx for category A engines.

   b. There shall be no more than 0.25 percent CO and no more than 0.20 percent NOx for category B engines.

3. **Gaseous emissions ventilation rate:** Ventilation rates necessary to dilute gaseous exhaust emissions to the following values shall be determined under §7.88 of this part:

Carbon dioxide . . . . –5000 ppm
Carbon monoxide . . . . – 50 ppm
Nitric oxide . . . . – 25 ppm
Nitrogen dioxide . . . . –5 ppm

A gaseous ventilation rate shall be determined for each requested speed and horsepower rating as described in §7.88(b) of this part.

4. **Fuel deration:** The fuel rates specified in the fuel deration chart shall be based on the tests conducted under paragraphs (b) and (c) of this section and shall ensure that the maximum fuel/air (f/a) ratio determined under paragraph (b) of this section is not exceeded at the altitudes specified in the fuel deration chart.

§7.85 Critical characteristics

The following critical characteristics shall be inspected or tested on each diesel engine to which an approval marking is affixed:

1. Fuel rate is set properly
2. Fuel injection pump adjustment is sealed, if applicable.

§7.90 Approval marking

Each approved diesel engine shall be identified by a legible and permanent approval marking inscribed with the assigned MSHA approval number and securely attached to the diesel engine. The marking shall also contain the following information:

1. Ventilation rate
2. Rated power
3. Rated speed
4. High idle
5. Maximum altitude before deration
6. Engine model number

30CFR Subpart F – Diesel Power Packages Intended for Use in Areas of underground Coal Mines where Permissible Electric Equipment is Required

§7.96 Definitions

In addition to the definitions in subparts A and E of this part, the following definitions apply in this subpart.

1. **Cylindrical joint:** A joint comprised of two contiguous, concentric, cylindrical surfaces.

2. **Diesel power package:** A diesel engine with an intake system, exhaust system, and a safety shutdown system installed.

3. **Dry exhaust conditioner:** An exhaust conditioner that cools the exhaust gas without direct contact with water.

4. **Exhaust system:** A system connected to the outlet of the diesel engine which includes, but is not limited to, the exhaust manifold, the exhaust pipe, the exhaust conditioner, the exhaust flame arrester, and any adapters between the exhaust manifold and exhaust flame arrester.

5. **Fastening:** A bolt, screw, or stud used to secure adjoining parts to prevent the escape of flame from the diesel power package.

6. **Flame arrester:** A device so constructed that flame or sparks from the diesel engine cannot propagate an explosion of a flammable mixture through it.

7. **Flame arresting path (explosion-proof joint):** Two or more adjoining or adjacent surfaces between which the escape of flame is prevented.

8. **Flammable mixture:** A mixture of methane or natural gas with normal air, which will propagate flame or explode when ignited.

9. **Grade:** The slope of an incline expressed as a percent.

10. **High idle speed:** The maximum no load speed specified by the engine manufacturer.
11. **Intake system:** A system connected to the inlet of the diesel engine, which included, but is not limited to, the intake manifold, the intake flame arrester,

the emergency intake air shutoff device, the air cleaner, and all piping and adapters between the intake manifold and air cleaner.

12. **Plane joint:** A joint comprised of two adjoining surfaces in parallel planes.

13. **Safety shutdown system:** A system which, in response to signals from various safety sensors, recognized the existence of a potentially hazardous condition and automatically shuts off the fuel supply to the engine.

14. **Step (rabbet) joint:** A joint comprised of two adjoining surfaces with a change or changes in direction between its inner and outer edges. A step joint may be composed of a cylindrical portion and a plane portion or of two or more plane portions.

15. **Threaded joint:** A joint consisting of a male and female-threaded member, both of which are the same type and gauge.

16. **Wet exhaust conditioner:** An exhaust conditioner that cools the exhaust gas through direct contact with water commonly called a water scrubber.

§7.98 Technical requirements

1. The diesel power package shall use a category "A" diesel engine approved under subpart E of this part with the following additional requirements:
    a. A hydraulic, pneumatic, or other mechanically actuated starting mechanism. Other means of starting shall be evaluated in accordance with the provisions of §7.107.

    b. If an air compressor is provided the intake air line shall be connected to the engine intake system between the air cleaner and the flame arrester. If the air compressor's inlet air line is not connected to the engine's intake system, it shall have an integral air filter.

2. **The temperature of any external surface of the diesel power package shall not exceed 302°F (150 °C).**
    a. When using water-jacketed components, provisions shall be made for positive circulation of coolant, venting of the system to prevent the accumulation of air pockets, and effective activation of the safety shutdown system before **the temperature of the coolant in the jackets exceeds the manufacturer's specifications or 212° F (100°C).**

3. All V-belts shall be static conducting and have a resistance not exceeding 6 megohms, when measured with a direct current potential of 500 volts or more.

4. The engine crankcase breather shall not be connected to the air intake system of the engine. The discharge from the breather shall be directed away from hot surfaces of the engine and exhaust system.

5. Electrical components on diesel power packages shall be certified or approved by MSHA under parts 7, 18, 20, and 27 of this chapter.

6. Electrical systems on diesel power packages consisting of electrical components, interconnecting wiring, and mechanical and electrical protection shall meet the requirements of parts 7, 18, and 27 of this chapter, as applicable.

7. The diesel power package shall be equipped with a safety shutdown system which will automatically shut off the fuel supply and stop the engine in response to signals from sensors indicating:

a. The coolant temperature limit specified in paragraph (2) of this section

b. The exhaust gas temperature limit specified §7.102 (1) of the next section

c. The minimum allowable low water level, for a wet exhaust conditioner, as established by tests in §7.100. Restarting of engine shall be prevented until the water level in the wet exhaust conditioner has been replenished above the minimum allowable low water level

§7.98 Technical requirements (Continued)

d. The presence of other safety hazards such as high methane concentration, actuation of the fire suppression system, etc., if such sensors are included in the safety shutdown system.

8. The safety shutdown system shall have the following features:

a. A means to automatically disable the starting circuit and prevent engagement of the starting mechanism while the engine is running, or a starting mechanism constructed of non-sparking materials.

b. If the design of the safety shutdown system requires that the lack of engine oil pressure must be overridden to start the engine, the override shall not be capable of overriding any of the safety shutdown sensors specified in paragraph (2) of this section.

9. Flexible connections shall be permitted in segments of the intake and exhaust systems required to provide explosion-proof features, provided that failure of the connection activates the safety shutdown system before the explosion-proof characteristics are lost.

§7.102 Exhaust gas cooling efficiency test

1. **Acceptable performance.**
   a. The exhaust gas temperature at discharge from a wet exhaust conditioner before the exhaust gas is diluted with air **shall not exceed 170°F (76°C).**

   b. The exhaust gas temperature at discharge from a dry exhaust conditioner before the gas is diluted with **air shall not exceed 302 °F (150 °C).**

§7.103 Safety system control test

1. Determine the effectiveness of the coolant system temperature shutdown sensors which will automatically activate the safety shutdown system and stop the engine before the coolant temperature in the cooling jackets exceeds manufacturer's specifications or 212 °F (100 °C), whichever is lower, by operating the engine and causing the coolant in the cooling jackets to exceed the specified temperature.

2. For systems using a dry exhaust gas conditioner, determine the effectiveness of the temperature sensor in the exhaust gas stream which will automatically activate the safety shutdown system and stop the engine before the cooled exhaust gas temperature exceeds 302 °F (150 °C), by operating the engine and causing the cooled exhaust gas to exceed the specified temperature.

3. For systems using a wet exhaust conditioner, determine the effectiveness of the temperature sensor in the exhaust gas stream which will automatically activate the safety shutdown system and stop the engine before the cooled exhaust gas temperature exceeds 185 °F (85 °C), with the engine operating at a high idle speed condition. Temporarily disable the reserve water supply,

if applicable, and any safety shutdown system control that might interfere with the evaluation of the operation of the exhaust gas temperature sensor. Prior to testing, set the water level in the wet exhaust conditioner to a level just above the minimum allowable low water level. Run the engine until the exhaust gas temperature sensor activates the safety shutdown system and stops the engine.

§7.105 Approval marking

Each approved diesel power package shall be identified by a legible and permanent approval plate inscribed with the assigned MSHA approval number and securely attached to the diesel power package in a manner that does not impair any explosion-proof characteristics. The grade limitation of a wet exhaust conditioner used as an exhaust flame arrester shall be included on the approval marking.

§7.108 Power package checklist

Each diesel power package bearing an MSHA approval plate shall be accompanied by a power package checklist. The power package checklist shall list specific features that must be checked and tests that must be performed to determine if a previously approved diesel power package is in approved condition. Test procedures shall be specified in sufficient detail to allow evaluation to be made without reference to other documents. Illustrations shall be used to fully identify the approved configuration of the diesel power package.

30 CFR PART 36: Approval Requirements for Permissible Mobile Powered Transportation Equipment

Subpart Part B-Construction and Design Requirements

§36.20 Quality of material, workmanship, and design

1. MSHA will test only equipment that in the opinion of its qualified representatives is constructed of suitable materials, is of good quality workmanship, based on sound engineering principles, and is safe for its intended use. Since all possible designs, arrangements, or combinations of components and materials cannot be foreseen, MSHA reserves the right to modify the construction and design requirements of subassemblies or components and test thereof to obtain the same degree of protection as provided by the tests described in Subpart C of this part.

2. The quality of material, workmanship, and design shall conform to the requirements of §7.98(q) of this chapter.

3. Power packages approved under part 7, subpart F of this chapter are considered to be acceptable for use in equipment submitted for approval under this part. Sections §36.21 through §36.26 (except §36.25 (f)) and §36.43 through §36.48 are not applicable to equipment utilizing part 7, subpart F power packages, since these requirements have already been satisfied.

§36.21 Engine for equipment considered for certification

Only equipment powered by a compression-ignition (diesel) engine and burning diesel fuel will be considered for approval and certification. The starting mechanism shall be actuated pneumatically, hydraulically, or by other methods acceptable to MSHA. Electric starting shall not be accepted. Engines burning other fuels or utilizing volatile fuel starting aids will not be investigated.

§36.22 Fuel injection system

This system shall be so constructed that the quantity of fuel injected can be controlled at a desired maximum value and shall be so arranged that this adjustment can be changed only after breaking a seal or unlocking a compartment. Provision shall be made for convenient adjustment of the maximum fuel-injection rate to that required for safe operation at different altitudes (elevations above sea level). The governor, controlling engine speed and fuel injection, shall not directly affect airflow to the engine and provisions shall be made to seal or lock its adjustment compartment. Filters shall be provided to ensure that only clean fuel will reach the injection pump or injectors.

§36.23 Engine intake system

1. Construction
   a. The intake system exclusive of the air cleaner shall be designed to withstand an internal pressure equal to 4 times the maximum pressure observed in explosion test, which are described in §36.46, or a pressure of 125 pounds per square inch, whichever is the lesser. Joints in the intake system shall be formed by metal flanges fitted with metal or metal-clad gaskets, positively positioned by through bolts or other suitable means for secure assembly or shall meet the requirements for flanged metal-to-metal flame-proof joints as required in §36.20(b). Either type of joint shall withstand repeated explosions within the intake system without permanent deformation and shall prevent the propagation of flame through the joint into a surrounding flammable mixture.

2. Intake flame arrester
   a. The intake system shall include a flame arrester that will prevent an explosion within the system from propagating to a surrounding flammable mixture. This flame arrester shall be between the air cleaner and the intake manifold and shall be attached so that it may be removed for inspecting, cleaning, or repairing. Its construction shall be such that it may be cleaned readily. The flame arrester shall be of rugged construction to withstand the effects of repeated explosions within the intake system, and the of construction shall resist deterioration in service. It shall be so mounted in the equipment assembly that it is protected from accidental external damage.

   b. The parts of any flame arrester shall be positively positioned to produce a flame path that will arrest the propagation of an explosion and shall be so designed that improper assembly is impossible. In flame arresters of the spaced-plate type, the thickness of the plates shall be at least 0.125 inch; spacing between the plates shall not exceed 0.018 inch; and the plates forming the flame path shall be at least 1 inch wide. The unsupported length of the plates shall be short enough that deformation during the explosion tests shall not exceed 0.002 Inch. Corrosion-resistant metal shall be used to construct flame arresters.

3. Air shutoff valve
    a. The intake system shall include a valve, operable from the operator's compartment, to shut off the air supply to the engine. This valve shall be constructed to permit its operation only after the fuel supply to the engine is shut off. In reverse operation the valve must open fully before fuel can be supplied to the engine.

4. Air cleaner
    a. An air cleaner shall be included in the engine intake system and so arranged that only clean air will enter the flame arrester. The resistance to airflow shall not increase rapidly in dusty atmospheres. Filters of the self-cleansing (oil-bath) type will be considered satisfactory for this application. Provision, satisfactory to MSHA, shall be made to prevent overfilling the oil-bath air cleaner.

5. Vacuum-gage connection. A connection shall be provided in the intake system for temporary attachment of a vacuum gage to indicate the pressure drop under flow conditions. This opening shall be closed by a plug or other suitable device that is sealed or locked in place except when a gage is attached.

§36.24 Engine joints

1. Cylinder head
    a. The joint between the cylinder head and block of the engine shall be fitted with a metal or metal-clad gasket satisfactory to MSHA held securely in position by through bolts or other suitable means to prevent a change in alignment. This joint shall provide an adequate flame barrier with the gasket in place.

2. Valve guides
    a. Valve guides shall be long enough to form an adequate flame barrier along the valve stem.

3. Gaskets.
    a. All metal or metal-clad gaskets shall maintain their tightness during repeated explosions within the engine and its intake and exhaust systems to prevent the propagation of flame.

§36.25 Engine exhaust system

1. Construction
   a. The exhaust system of the engine shall be designed to withstand an internal pressure equal to 4 times the maximum pressure observed in explosion tests, which are described in §36.46, or a pressure of 125 pounds per square inch, whichever is the lesser. The system shall withstand repeated internal explosions without permanent deformation or deterioration.

2. Exhaust flame arrester.
   a. The exhaust system of the engine shall be provided with a flame arrester to prevent propagation of flame or discharge of heated particles to a surrounding flammable mixture. The flame arrester shall be so positioned that only cooled exhaust gas will discharge through it and shall be so designed and attached that it can be removed for inspecting, cleaning, or repairing. Its construction shall be rugged construction to withstand the effects of repeated explosions within the exhaust system, and the material of construction shall resist deterioration in service. It shall be so mounted in the equipment assembly that it is protected from accidental external damage.

   b. A spaced-plate flame arrester for the exhaust system shall meet the same requirements as flame arresters for the intake system *-see §36.23 (2)*

   c. In lieu of a space-plate flame arrester, an exhaust-gas cooling box or conditioner may be used as the exhaust flame arrester provided that explosions tests demonstrate that the cooling box will arrest flame. When used as a flame arrester the cooling box shall be equipped with a device to shut off automatically the fuel supply to the engine at a safe minimum water level. A cooling box used as a flame arrester shall withstand repeated explosion tests without permanent deformation. It shall be constructed of material, satisfactory to MSHA that will resist deterioration in service.

3. Exhaust cooling system.
   a. A cooling system shall be provided for the engine exhaust gas. The heat-dissipation capacity shall be capable of reducing the temperature of the undiluted exhaust gas to less than 170° Fahrenheit at the point of discharge from the cooling system under any condition of engine operation acceptable to MSHA. A device shall be provided that will automatically shut off the fuel supply to the engine immediately if the

temperature of the exhaust gas exceeds 185° Fahrenheit at the point of discharge from the cooling system. Provision shall be made, acceptable to MSHA, to prevent restarting the engine after the fuel supply has been replenished. When the cooling box is used as a flame arrester, one safety device may be accepted provided it controls a safe minimum water level in the cooling box and prevents the final exhaust temperature from exceeding 185° Fahrenheit.

b. Cooling shall be obtained by passing the exhaust gas through water or a dilute aqueous chemical solution that will enter the exhaust system near the outlet of the exhaust manifold, or a combination the two methods. When a spray is used it shall be provided with a filtering device to protect the nozzle from clogging. Provisions shall be made for draining and cleaning all parts of the exhaust cooling system. Openings for draining and cleaning shall be closed and sealed or locked by a method satisfactory to MSHA.

c. The cooling system shall be constructed of corrosion-resistant metal suitable for the intended application.

d. The cooling system shall store enough water or aqueous solution to permit operation of the engine at one-third load factor for eight hours. The minimum quantity of usable water or aqueous solution available for cooling shall equal the consumption for one hour with the engine operating at maximum load and speed multiplied by 8 and this product divided by 3.

4. Surface temperature of engine and exhaust system.

a. The temperature of any external surface of the engine or exhaust system shall not exceed 400 degrees Fahrenheit under any condition of engine operation prescribed by MSHA. Water-jacketed components shall have integral jackets and provisions shall be made for positive circulation of water in the jackets and to automatically shut off the engine when the temperature in the cooling jacket(s) exceeds 212 degrees Fahrenheit. Insulated coverings to control surface temperature are not acceptable.

5. Pressure-gage connection. A connection shall be provided in the exhaust system for convenient, temporary attachment of a pressure gage at a point suitable for measuring the total back pressure in the system. The connection also, shall be suitable for temporary attachment of gas-sampling equipment to the exhaust system. This opening shall be closed by a plug or other suitable device that is sealed or locked in place except when a gage or sampling tube is attached.

§36.27 Fuel supply system.

1. Fuel tank
    a. The fuel tank shall not leak and shall be fabricated of metal at least 1/16 inch thick, welded at all seams, except that tanks of 5 gallons or less capacity may have thinner walls which shall be performed or reinforced to provide good resistance to deflection. A drain plug (not a valve or petcock) shall be provided and locked in position. A vent opening shall be provided in the fuel filler cap of such design that atmospheric pressure is maintained inside the tank. The size of the vent opening shall be restricted to prevent fuel from splashing through it. The filler opening shall be so arranged that fuel can be added only through a self-closing valve at least 1 foot from the exhaust manifold of the engine, preferably below it. The self-closing valve shall constitute a fuel-tight closure when fuel is not being added. Any part of the self-closing valve that might become detached during the addition of fuel shall be secured to the tank by a chain or other fastening to prevent loss.

    b. The fuel tank shall have a definite position in the equipment assembly, and no provision shall be made for attachment of separate or auxiliary fuel tanks.

    c. Capacity of the fuel tank shall not exceed the amount of fuel necessary to operate the engine continuously at full load for approximately four hours.

2. Fuel lines
    a. All fuel lines shall be installed to protect them against damage in ordinary use and they shall be designed, fabricated, and secured to resist breakage from vibration.

3. Valve in fuel line
    a. A shutoff valve shall be provided in the fuel system, installed in a manner acceptable to MSHA.

30 CFR PART 70 Mandatory Health Standards – Underground Coal Mines

Subpart T – Diesel Exhaust Gas Monitoring

§70.1900 Exhaust gas monitoring

1. During on-shift examinations required by §75.362, a certified person as defined by §75.100 of this chapter and designated by the operator as trained or experienced in the appropriate sampling procedures, shall determine the concentration of carbon monoxide (CO) and nitrogen dioxide (NO_2):
   a. In the return of each working section where diesel equipment is used, at a location which represents the contribution of all diesel equipment on such section

   b. In the area of the section loading point if diesel haulage equipment is operated on the working section.

   c. At a point inby the last piece of diesel equipment on the longwall or shortwall face when mining equipment is being installed or removed

   d. In any other area designated by the district manager as specified in the mine operator's approved ventilation plan where diesel equipment is operated in a manner which can result in significant concentrations of diesel exhaust.

2. Samples of CO and NO_2 shall be:
   a. Collected in a manner that makes the results available immediately to the person collecting the samples

   b. Collected and analyzed by appropriate instrumentation which has been maintained and calibrated in accordance with the manufacturer's recommendations

   c. Collected during periods that are representative of conditions during normal operations.

3. Except as provided in §75.325(?) of this chapter, when sampling results indicate a concentration of CO and/or NO_2 exceeding an action level of 50% of the threshold limit values (TLV®) adopted by the American Conference of Governmental Industrial Hygienists, the mine operator shall immediately take appropriate corrective action to reduce the concentrations

of CO and/or NO_2 to below the applicable action level. The publication, "Threshold Limit Values for Substance in Workroom Air" (1972) is incorporated by reference and may be inspected at MSHA's Office of Standards, Regulations, and Variances, 4015 Wilson Boulevard, Arlington, VA 22203; at any Coal Mine Health and Safety District and Sub district Office; and at the Office of the FEDERAL REGISTER, 800 North Capitol Street, NW Suite 700, Washington, DC. This incorporation by reference was approved by the Director of the Federal Register in accordance with 5 U.S.C. 552(a) and 1 CFR part 51. In addition, copies of the document may be purchased from the Secretary-Treasurer, American Conference of Governmental Industrial Hygienists, Post Office Box 1937, Cincinnati, OH 45202.

4. A record shall be made when sampling results exceed the action level for the applicable TLV® for CO and/or NO_2. The record shall be made as part of and in the same manner as the records for hazards required by 75.363 of this chapter and include the following:

   a. Location where each sample was collected

   b. Substance sampled and the measured concentration

   c. Corrective action taken to reduce the concentration of CO and/or NO_2 to or below the applicable action level.

   d. As of November 25, 1997 exhaust gas monitoring shall be conducted in accordance with the requirement of this section.

30 CFR PART 72 Health Standards for Coal Mines

Subpart D – Diesel Particulate Matter – Underground Areas of Underground Coal Mines

§72.500 Emission limits for permissible diesel-powered equipment

1. Each piece of permissible diesel-powered equipment **introduced** into an underground area of an underground coal mine after March 20, 2001not emit no more than 2.5 grams per hour of diesel particulate matter.
2. As of July 19, 2002, each piece of permissible diesel-powered equipment **operated** in an underground area of an underground coal mine must not emit no more than 2.5 grams per hour of diesel particulate matter.

§72.501 Emission limits for non-permissible heavy-duty diesel-powered equipment, generators, and compressors

1. As of January 19, 2005, each piece of non-permissible heavy-duty diesel-powered equipment (as defined by §75.1908(a) of this part), generator or compressor operated in an underground area of an underground coal must not emit no more than 2.5 grams per hour of diesel particulate matter.

2. Not withstanding the other provisions of this section, a generator or that discharges its exhaust directly into intake air that coursed directly to a return air course or discharges its exhaust directly into a return air course, is not subject to the applicable requirements of this section.

§72.502 Requirements for non-permissible light-duty diesel-powered equipment, other generators, and compressors

1. Each piece of non-permissible light-duty diesel-powered equipment (as defined by §75.1908(b) of this part), generator or compressor introduced into an underground area of an underground coal mine after March 20, 2001, must not emit no more than 5.0 grams per hour of diesel particulate matter.

2. A piece of non-permissible light-duty diesel-powered equipment must be deemed to be in compliance with the requirements of paragraph (1) of this section if it utilizes an engine, which meets or exceeds the applicable particulate matter emission requirements of the Environmental Protection Administration listed in Table 72.502-1, as follows:

TABLE 72.502-1

EPA requirement	EPA category	PM limit
40 CFR 86.094-8(a)(1)(I)(A)(2)	light duty vehicle	0.1 g/mile.
40 CFR 86.094-9(a)(1)(I)(A)(2)	light duty truck	0.1g/mile.
40 CFR 86.094-11(a)(1)(iv)(B)	heavy duty highway engine	0.1g/bhp-hr.
40 CFR 89.112(a)	tier 2 nonroad	Varies by power.
	kW<(hp<11)	0.80g/kW-hr(0.60 g/bhp-hr).
	8 ≤ kW<19(11≤hp<25)	0.80g/kW-hr(0.60 g/bhp-hr).
	19≤kW<37(25≤hp<50)	0.60g/kW-hr(0.45 g/php-hr).
	37≤kW<75 (50≤hp<100)	0.40g/kW-hr(0.30g/bhp-hr).
	75≤kW<130(100≤hp<175)	0.30g/kW-hr(0.22 g/bhp-hr).
	130≤kW<225(175≤hp<300)	0.20g/kW-hr(0.15g/bhp-hr).
	225≤kW<450(300≤hp<600)	0.20g/kW-hr(0.15g/bhp-hr).

Notes: "g" means grams; "kW" means kilowatt; "hp" means horsepower; "g/kW-hr" means grams/ kilowatt-hour; "g/bhp-hr" means grams/brake horsepower-hour.

3. The requirements of this section do not apply to any diesel-powered ambulance or fire fighting equipment that is being used in accordance with the mine fire fighting and evacuation plan under §75.1101-23.

<u>§72.503 Determination of emissions; filter maintenance; definition of "introduced"</u>

1. MSHA will determine compliance with the emission requirements by this part by using the amount of diesel particulate matter emitted by a particular engine determined from the engine approval pursuant to §7.89(a) (9) (iii) (B) or §7.89(a) (9) (iv) (A) of this title, with the exception of engines deemed to be in compliance by meeting the EPA requirements specified in Table 72.502-1 [§72.502(b)].

2. Except as provided in paragraph (3) of this section, the amount by which an aftertreatment device can reduce engine emissions of diesel particulate matter as determined pursuant to paragraph (1) must be established by a laboratory test:

a. on an approved engine which MSHA has determined, pursuant to paragraph (1) of this section, to emit no more diesel particulate matter than the engine being used in the piece of diesel-powered equipment in question.

b. Using the test cycle specified in Table E-3 of §7.89 of this title, and following a test procedure appropriate for the filtration system, by a laboratory capable of testing engines in accordance with the requirements of Subpart E of part 7 of this title.

c. With an aftertreatment device representative of that being used on the piece of diesel-powered equipment in question.

3. In lieu of the laboratory tests required by paragraph (2), the Secretary may accept the results of tests conducted or certified by an organization whose testing standards are deemed by the Secretary to be as rigorous as those set forth by paragraph (2) of this section; and further, the Secretary may accept the results of tests for one aftertreatment device as evidencing the efficiency of another aftertreatment device which the Secretary determines to be essentially identical to the one tested.

4. Operators must maintain in accordance with manufacturer specifications and free of observable defects, any aftertreatment device installed on a piece of diesel equipment upon which the operator relies to remove diesel particulate matter from diesel emissions.

5. For purposes of §72.500(a), §72.501(a) and §72.502(a), the term "introduced" means any piece of equipment whose engine is a new addition to the underground inventory of engines of the mine in question, including newly purchased equipment, used equipment, and equipment receiving a replacement engine that has a different serial number than the engine it is replacing. "Introduced" does not include a piece of equipment whose engine was previously part of the mine inventory and rebuilt.

§72.510 Miner health training.

1. Operators must provide annual training to all miners at a mine who can reasonably be expected to be exposed to diesel emissions on that property. The training must include:
   a. The health risks associated with exposure to diesel particulate matter
   b. The methods used in the mine to control diesel particulate matter concentrations
   c. Identification of the personnel responsible for maintaining those controls
   d. Actions miners must take to ensure the controls operate as intended.

2. **An operator must keep a record of the training at the mine site for one year after completion of the training**. An operator may keep the

record elsewhere if the record is immediately accessible from the mine site by electronic transmission.

3. Upon request from an authorized representative of the Secretary of Labor, the Secretary of Health and Human Services, or from the authorized representative of miners, mine operators must promptly provide access to any such training record. Whenever an operator ceases to do business, that operator must transfer the training records, or a copy, to any successor operator who must maintain them for the required period.

§72.520 Diesel equipment inventory.

1. The operator of each mine that utilizes diesel equipment underground shall prepare and submit in writing to the District Manager, an inventory of diesel equipment used in the mine. The inventory shall include the number and type of diesel-powered units used underground, including make and model of unit, type of equipment, make and model of engine, serial number of engine, brake horsepower rating of engine, emissions of engine in grams per hour or grams per brake horsepower-hour, approval number of engine, make and model of aftertreatment device, serial number of aftertreatment device if available, and efficiency of after treatment device.

2. The mine operator shall make changes to the diesel equipment inventory as equipment or emission control systems are added, deleted or modified and submit revisions, to the District Manager, within 7 calendar days. **If requested, the mine operator shall provide a copy of the diesel equipment inventory to the representative of the miners within 3 days of the request.**

Example of on-line diesel inventory:

UNITED STATES DEPARTMENT OF LABOR

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Mine Id 4407308
Mine Name Deep Mine 44
Operator Paramont Contura, LLC
District C0501, Norton VA Field Office

*** Engine is EPA Compliant**

#	Equipment	Engine	After Treatment
# 1	**JD-004** - Not Shared Johnson Industries Little Diesel Light Duty, Personnel Carrier (Mine Tndr, Mantrip, Rabit, Bosbusy, Ribrnr Serial #: LD-004 Approval #:	MITSUBISHI S3L2-Y361 DPH 28 @ 3000 HP Emissions: 1.98 G/Hr Serial #: 202058 Approval #: 07-ENA110016 *	
# 2	**JD-001** - Not Shared Johnson Industries Little Diesel Light Duty, Personnel Carrier (Mine Tndr, Mantrip, Rabit, Bosbusy, Ribrnr Serial #: LD-001 Approval #:	MITSUBISHI S3L2-Y361 DPH 28 @ 3000 HP Emissions: 1.98 G/Hr Serial #: 201349 Approval #: 07-ENA110016 *	
# 3	**AC-1** - Not Shared al lee corp m76 m76 Light Duty, Air Compressor Serial #: 1015 Approval #:	DEUTZ BF4L 1011F 74 @ 2800 HP Emissions: 7.65 G/Hr Serial #: 02-74-70 Approval #: 7E-B019 *	
# 4	**DM050** - Not Shared A.L.Lee A.L.Lee Light Duty, Tractor Serial #: E-9125 Approval #:	DEUTZ BF4M2012C 138 @ 2500 HP Emissions: 4.57 G/Hr Serial #: 10370648 Approval #: 07-ENA040003 *	

30 CFR PART 75 Mandatory Safety Standards Underground Coal Mines

Subpart D – Ventilation

§75.325 Air quantity

1. The minimum ventilating air quantity for an individual unit of diesel-approval plate for that equipment. Such air quantity shall be maintained
   a. In any working place where the equipment is being operated

   b. At the section loading point during any shift the equipment is being operated on the working section

   c. In any entry where the equipment is being operated outby the section loading point in areas of the mine developed on or after April 25, 1997

   d. In any air course with single or multiple entries where the equipment is being operated outby the section loading point in areas of the mine developed prior to April 25, 1997

   e. At any other location required by the district manager and specified in the approved ventilation plan.

2. The minimum ventilating air quantity where multiple units of diesel-powered equipment are operated on working sections and in areas where mechanized mining equipment is being installed or removed must be at least the sum of that specified on the approval plates of all the diesel-powered equipment on the working section or in the area where mechanized mining equipment is being installed or removed. The minimum ventilating air quantity shall be specified in the approved ventilation plan. For working sections such air quantity must be maintained:
   a. In the last open crosscut of each set of entries or rooms in each working section

   b. In the intake, reaching the working face of each longwall

   c. At the intake end of any pillar line.

§75.325 Air quantity (Continued)

3. The following equipment may be excluded from the calculations of ventilating air quantity under paragraph (g) if such equipment exclusion is approved by the district manager and specified in the ventilation plan:
    a. Self-propelled equipment meeting the requirements of §75.1908(2)
    b. Equipment that discharges its exhaust into intake air that is coursed directly to a return air course
    c. Equipment that discharges its exhaust directly into a return air course
    d. Other equipment having duty cycles such that the emissions would not significantly affect the exposure of miners.
4. A ventilating air quantity that is less than what is required by paragraph "g" of this section may be approved by the district manager in the ventilation plan based upon the results of sampling that demonstrate that the lesser air quantity will maintain continuous compliance with applicable TLV®'s.
5. If during sampling required by §70.1900(c) of this subchapter the ventilating air is found to contain concentrations of CO or NO_2 in excess of the action level specified by §70.1900(c), higher action levels may be approved by the district manager based on the results of sampling that demonstrate that a higher action level will maintain continuous compliance with applicable TLV®'s. Action levels other than those specified in §70.1900(c) shall be specified in the approved ventilation plan.
6. As of November 25, 1997 the ventilating air quantity required where diesel-powered equipment is operated shall meet the requirements of paragraphs (4) through (10) of this section. Mine operators utilizing diesel-powered equipment in underground coal mines shall submit to the appropriate MSHA district manager a revised ventilation plan or appropriate amendments to the existing plan, in accordance with §75.371, which implement the requirements of paragraphs (6) through (10) of this section.

§75.371 Mine ventilation plan; contents

7. The minimum quantity of air that will be provided during the installation and removal of mechanized mining equipment, the location where this

quantity will be provided, and the ventilation controls that will be used (see §75.325(4), (7), and (9)).

8. Areas designated by the district manager where measurements of CO and NO_2 concentrations will be made (see §70.1900(1) (d)).

9. Location where the air quantity will be maintained at the section loading point (see §75.325(6)(b)).

10. Any additional location(s) required by district manager where a minimum air quantity must be maintained for an individual unit of diesel-powered equipment.

Subpart E – Combustible Materials and Rock Dusting

§75.400 Accumulation of Combustible Materials

Coal dust, including float coal dust deposited on rock-dusted surfaces, loose coal, and other combustible materials, shall be cleaned up and not be permitted to accumulate in active workings, or on diesel-powered and electric equipment therein.

Subpart T – Diesel Powered Equipment

§75.1900 Definitions

The following definitions apply in this subpart.

1. **Diesel fuel tank:** a closed metal vessel specifically designed for the storage or transport of diesel fuel.

2. **Diesel fuel transportation unit:** a self-propelled or portable wheeled vehicle used to transport a diesel fuel tank.

3. **Permanent underground diesel fuel storage facility:** A facility designed and constructed to remain at one location for the storage or dispensing of diesel fuel, which does not move as mining progresses.

4. **Safety can:** A metal container intended for storage, transport or dispensing of diesel fuel, with a nominal capacity of 5 gallons, listed or approved by a nationally recognized independent testing laboratory.

5. **Temporary underground diesel fuel storage area:** An area of the mine provided for the short-term storage of diesel fuel in a fuel transportation unit, which moves as mining progresses.

§75.1901 Diesel fuel requirements

1. Diesel-powered equipment shall be used underground only with a diesel fuel having a sulfur content no greater than 0.05 percent and a flash point of 100°F (38°C) or greater. Upon request, the mine operator shall provide to an authorized representative of the Secretary evidence that the diesel fuel purchased for use in diesel-powered equipment underground meets these requirements.

2. Flammable liquids shall not be added to diesel fuel used in diesel-powered equipment underground.

3. Only diesel fuel additives that have been registered by the Environmental Protection Agency may be used in diesel-powered equipment underground.

§75.1902 Underground diesel fuel storage – general requirements

1. All diesel fuel must be stored in:
    a. Diesel fuel tanks in permanent underground diesel fuel storage facilities.

    b. Diesel fuel tanks on diesel fuel transportation units in permanent underground diesel fuel storage facilities or in temporary underground fuel storage areas

    c. Safety cans.

2. The total capacity of stationary diesel fuel tanks in permanent underground diesel fuel storage facilities must not exceed 1000 gallons.

3.
    a. Only one temporary underground diesel fuel storage area is permitted for each working section or in each area of the mine where equipment is being installed or removed.

    b. The temporary underground diesel fuel storage area must be located:
        i. Within 500 feet of the loading point

   ii. Within 500 feet of the projected loading point where equipment is being installed
   iii. Within 500 feet of the last loading point where equipment is being removed
c. No more than one diesel fuel transportation unit at a time shall be parked in the temporary underground diesel fuel storage area.

4. Permanent underground diesel fuel storage facilities and temporary underground diesel fuel storage areas must be:
   a. At least 100 feet from shafts, slopes, shops, or explosives magazines.

   b. At least 25 feet from trolley wires or power cables, or electric equipment not necessary for the operation of the storage facilities or areas.

   c. In a location that is protected from damage by other mobile equipment.

5. Permanent underground diesel fuel storage facilities must not be located within the primary escapeway.

§75.1903 Underground diesel fuel storage facilities and areas, construction and safety precautions

1. Permanent underground diesel fuel storage facilities must be:
   a. Constructed of noncombustible materials, including floors, roofs, roof supports, doors, and door frames. Exposed coal within fuel storage areas must be covered with noncombustible materials. If bulkheads are used, they must be covered with noncombustible materials. If bulkheads are used they must be tightly sealed and must be built of or covered with noncombustible materials.

   b. Provided with either self-closing doors or a means for automatic enclosure

   c. Provided with a means for personnel to enter and exit the facility after closure

   d. Ventilated with intake air that is coursed into a return air course or to the surface and that is not used to ventilate working places, using ventilation controls meeting the requirements of §75.333(5)

e. Equipped with an automatic fire suppression system that meets the requirements of §75.1912. Actuation of the automatic fire suppression system shall initiate the means for automatic enclosure

f. Provided with a means of containment capable of holding 150 percent of the maximum capacity of the fuel storage system

g. Provided with a competent concrete floor or equivalent to prevent fuel spills from saturating the mine floor

2. Permanent underground diesel fuel storage facilities and temporary underground diesel fuel storage areas must be:

a. **Equipped with at least 240 pounds of rock dust and provided with two portable multipurpose dry chemical type (ABC) fire extinguishers** that are listed or approved by a nationally recognized independent testing laboratory and have a 10A:60B:C or higher rating. Both fire extinguishers must be easily accessible to personnel, and at least one fire extinguisher must be located outside of the storage facility or area upwind of the facility, in intake air.

b. Provided with three portable multipurpose dry chemical type (ABC) fire extinguishers that are listed or approved by a nationally recognized independent testing laboratory and have a 10A:60B:C or higher rating. All fire extinguishers must be easily accessible to personnel, and at least one fire extinguisher must be located outside of the storage facility or area upwind of the facility, in intake air.

c. Identified with conspicuous markings designating diesel fuel storage

d. Maintained to prevent the accumulation of water.

3. Welding or cutting other than that performed in accordance with paragraph (4) of this section shall not be performed within 50 feet of a permanent underground diesel fuel storage facility or a temporary underground diesel fuel storage area.

4. When it is necessary to weld, cut, or solder pipelines, tanks, or other containers that may have contained diesel fuel, these practices shall be followed:

a. Cutting or welding shall not be performed on or within pipelines, tanks, or other containers that have contained diesel fuel until the have been thoroughly purged and cleaned or inserted and a vent or opening is provided to allow for sufficient release of any buildup pressure before heat is applied.

b. Diesel fuel shall not be allowed to enter pipelines, tanks, or containers that have been welded, soldered, brazed, or cut until the metal has cooled to ambient temperature.

§75.1904 Underground diesel fuel tanks and safety cans

1. Diesel fuel tanks used underground shall:
    a. Have steel walls of a minimum 3/16-inch thickness, or walls made of other metal of a thickness that provides equivalent strength

    b. Be protected from corrosion

    c. Be of seamless construction or have liquid tight welded seams

    d. Not leak

    e. For stationary tanks in permanent underground diesel fuel storage facilities, be placed on supports constructed of noncombustible material so that the tanks are at least 12 inches above the floor.

2. Underground diesel fuel tanks must be provided with:
    a. Devices for emergency venting designed to open at a pressure not to exceed 2.5 psi according to the following:
        i. Tanks with a capacity greater than 500 gallons must have an emergency venting device whose area is equivalent to a pipe with a nominal inside diameter of 5 inches or greater

        ii. Tanks with a capacity of 500 gallons or less must have an emergency venting device whose area is equivalent to a pipe with a nominal inside diameter of 4 inches or greater.

    b. Tethered or self-closing caps for stationary tanks in permanent underground diesel fuel storage facilities and self-closing caps for diesel fuel tanks on diesel fuel transportation units

    c. Vents to permit the free discharge of liquid, at least as large as the fill or withdrawal connection, whichever is larger, but not less than 1 ¼ inch nominal inside diameter

d. Liquid tight connections for all tank openings that are:
    i. Closed when not in use

e. Vent pipes that drain toward the tank without sagging and are higher than the fill pipe openings

f. Shutoff valves located as close as practicable to the tank shell on each connection through which liquid can normally flow

g. An automatic closing, heat-actuated valve on each withdrawal connection below the liquid level.

3. When tanks are provided with openings for manual gauging, liquid tight, tethered or self-closing caps, or covers must be provided and must be kept closed when not open for gauging.

4. Surfaces of the tank and its associated components must be protected against damage by collision.

5. Before being placed in service, tanks and their associated components must be tested for leakage at a pressure equal to the working pressure, except tanks and components connected directly to piping systems, which must be properly designed for the application.

6. Safety cans must be:

a. Limited to a nominal capacity of 5 gallons or less

b. Equipped with a flexible or rigid tubular nozzle attached to a valve spout

c. Provided with a vent valve designed to open and close simultaneously and automatically with the opening and closing of the pouring valve

d. Designed so that they will safely relieve internal pressure when exposed to fire.

§75.1905 Dispensing of diesel fuel

1. Diesel-powered equipment in underground coal mines may be refueled only from safety cans, from tanks on diesel fuel transportation units, or from stationary tanks.

2. Fuel that is dispensed from other than safety cans must be dispensed by means of:
   a. Gravity feed with a hose equipped with a nozzle with a self-closing valve and no latch-open device

   b. A manual pump with a hose equipped with a nozzle containing a self-closing valve; or

   c. A powered pump with:
      i. An accessible emergency shutoff switch for each nozzle
      ii. A hose equipped with a self-closing valve and no latch-open device
      iii. An anti-siphoning device

3. Diesel fuel must not be dispensed using compressed gas

4. Diesel fuel must not be dispensed to the fuel tank or diesel-powered equipment while the equipment engine is running

5. Powered pumps shall be shut off when fuel is not being dispensed.

§75.1905-1 Diesel fuel piping systems

1. Diesel fuel piping systems from the surface must be designed and operated as dry systems, unless an automatic shutdown is incorporated that prevents accidental loss or spillage of fuel and that activates an alarm system.

2. All piping, valves and fittings must be:
   a. Capable of withstanding working pressures and stresses
   b. Capable of withstanding four times the static pressures
   c. Compatible with diesel fuel
   d. Maintained in a manner that prevents leakage

3. Pipelines must have manual shutoff valves installed at the surface filling point, and at the underground discharge point.

4. If diesel fuel lines are not buried in the ground sufficiently to protect them from damage, shutoff valves must be located every 300 feet.

5. Shutoff valves must be installed at each branch line where the branch line joins the main line.

6. An automatic means must be provided to prevent unintentional transfer of diesel fuel from the surface into the permanent underground diesel fuel storage facility.

7. Diesel fuel piping systems from the surface shall only be used to transport diesel fuel directly to stationary tanks or diesel fuel transportation units in a permanent underground diesel fuel storage facility.

8. The diesel fuel piping system must not be located in a borehole with electric power cables.

9. Diesel fuel piping systems located in entries must not be located on the same side of the entry as electric cables or power lines. Where it is necessary for piping systems to cross electric cables or power lines, guarding must be provided to prevent severed electrical cables or power lines near broken fuel lines.

10. Diesel fuel piping systems must be protected and located to prevent physical damage.

§75.1906 Transport of Diesel Fuel

1. Diesel fuel shall be transported only by diesel fuel transportation units or in safety cans.

2. No more than one safety can shall be transported on a vehicle at any time. The can must be protected from damage during transport. All other safety cans must be stored in permanent underground diesel fuel storage facilities.

3. Safety cans that leak must be promptly removed from the mine.

4. Diesel fuel transportation unit tanks and safety cans must be conspicuously marked as containing diesel fuel.

5. Diesel fuel transportation units must transport no more than 500 gallons of diesel fuel at a time.

6. Tanks on diesel fuel transportation units must be permanently fixed to the unit and have a total capacity of no greater than 500 gallons of diesel fuel.

7. Non-self-propelled diesel fuel transportation units with electrical components for dispensing fuel that are connected to a source of electrical

power must be protected by a fire suppression device that meets the requirements of §75.1107-3 through §75.1107-6 and §75.1107-8 and §75.1107-16.

8. Diesel fuel transportation units and vehicles transporting safety cans containing diesel fuel must have at least two multipurpose, dry chemical type (ABC) fire extinguishers, listed or approved by a nationally recognized independent testing laboratory and having a 10A:60B:C or higher rating, with one fire extinguisher provided on each side of the vehicle.

9. Diesel fuel transportation units shall be parked only in permanent underground diesel fuel storage facilities or temporary underground diesel fuel storage areas when not in use.

10. When the distance between a diesel fuel transportation unit and an energized trolley wire at any location is less than 12 inches, the requirement of §75.1003-2 must be followed.

11. Diesel fuel shall not be transported on or with mantrips or on conveyor belts.

§75.1907 Diesel-Powered Equipment Intended for Use in Underground Coal Mines

1. As of November 25, 1996 all diesel-powered equipment used where permissible electrical equipment is required must be approved under part 36 of this chapter.

2. Diesel-powered equipment approved under part 36 of this chapter must be provided with additional safety features in accordance with the following time schedule:

   a. As of April 25, 1997 the equipment must have a safety component system that limits surface temperatures to those specified in subpart F of part 7 of this title.

   b. As of November 25, 1999 the equipment must have an automatic or manual fire suppression system that meets the requirements of §75.1911 of this part, and at least one portable multipurpose dry chemical type (ABC) fire extinguisher, listed or approved by a nationally recognized independent testing laboratory and having a 10A:60B:C or higher rating. The fire extinguisher must be located within easy reach of the equipment operator and be protected from damage by collision.

c. As of November 25, 1999, the equipment must have a brake system that meets the requirements of §75.1909 (2) (f), (2) (g), (2) (h), (3), (4), and (5)

d. As of November 25, 1997, a particulate index and dilution air quantity shall be determined for the equipment in accordance with subpart E of part 7 of this chapter

e. Permissible diesel-powered equipment manufactured on or after November 25, 1999, and that is used in an underground coal mine shall incorporate a power package approved in accordance with part 7, subpart F of this chapter.

3. As of November 25, 1999, non-permissible diesel-powered equipment, except the special category of equipment under §75.1908(4), shall meet the requirements of §75.1909 and §75.1910 of this part.

§75.1908 Non-Permissible Diesel-Powered Equipment-Categories

1. Heavy-duty diesel-powered equipment includes:

a. Equipment that cuts or moves rock or coal

b. Equipment that performs drilling or bolting functions

c. Equipment that moves longwall components

d. Self-propelled diesel fuel transportation units and self-propelled lube units; or

e. Machines used to transport portable diesel fuel transportation units or portable lube units.

2. Light-duty diesel-powered equipment is any diesel-powered equipment that does not meet the criteria of paragraph (1).

3. For the purposes of this subpart, the following equipment is considered attended:

a. Any machine or device operated by a miner; or

b. Any machine or device that is mounted in the direct line of sight of a job site located within 500 feet of such machine or device, which job site is occupied by a miner.

4. Diesel-powered ambulances and firefighting equipment are a special category of equipment that may be used underground only in accordance with the mine firefighting and evacuation plan under §75.1101-23.

§75.1909 Non-Permissible Diesel-Powered Equipment

Design and Performance Requirements

1. Non-permissible diesel-powered equipment, except for the special category of equipment under §75.1908(4), must be equipped with the following features:

a. An engine approved under subpart E of part 7 of this title equipped with an air filter sized in accordance with the engine manufacturer's recommendations, and an air filter service indicator set in accordance with the engine manufacturer's recommendations.

b. At least one portable multipurpose dry chemical type (ABC) fire extinguisher listed or approved by a nationally recognized independent testing laboratory with a 10A:60B:C or higher rating. The fire extinguisher must be located within easy reach of the equipment operator and protected from damage

c. A fuel system specifically designed for diesel fuel meeting the following requirements:

i. A fuel tank and fuel lines that do not leak

ii. A fuel tank that is substantially constructed and protected against damage by collision

iii. A vent opening that maintains atmospheric pressure in the fuel tank, and that is designed to prevent fuel from splashing out of the vent opening.

iv. A self-closing filler cap on the fuel tank

v. The fuel tank, filler and vent must be located so that leaks or spillage during refueling will not contact hot surfaces

vi. Fuel line piping must be either steel-wire reinforced, synthetic elastomer-covered hose suitable for use with diesel fuel that has been tested and has been determined to be fire-resistant by the manufacturer, or metal

vii. Fuel line piping must be clamped

viii. Primary fuel lines must be located so that fuel line leaks do not contact hot surfaces

ix. The fuel lines must be separated from electrical wiring and protected from damage in ordinary use

x. A manual shutoff valve must be installed in the fuel system as close as practical to the tank

xi. A water separator and fuel filter(s) must be provided.

d. A sensor to monitor the temperature and provide a visual warning of an overheated cylinder head on air-cooled engines

e. Guarding to protect fuel, hydraulic, and electric lines when such lines pass near rotating parts or in the event of shaft failure

f. Hydraulic tanks, fillers, vents, and lines located to prevent spillage or leaks from contacting hot surfaces

g. Reflectors or warning lights mounted on the equipment which can be readily seen in all directions

h. A means to direct exhaust gas away from the equipment operator, persons on board the machine, and combustible machine components

i. A means to prevent unintentional free and uncontrolled descent of personnel-elevating work platforms

j. A means to prevent the spray from ruptured hydraulic or lubricating oil lines from being ignited by contact with engine exhaust system component surfaces.

2. Self-propelled non-permissible diesel-powered equipment must have the following features in additions to those in paragraph (1):

a. A means to ensure that no stored hydraulic energy that will cause machine articulation is available after the engine is shut down

b. A neutral start feature which ensures that engine cranking torque will not be transmitted through the power train and cause machine movement on vehicles utilizing fluid power transmissions

c. For machines with steering wheels, brake pedals, and accelerator pedals, controls which are of automobile orientation

d. An audible warning device conveniently located near the equipment operator

e. Lights provided and maintained on both ends of the equipment. Equipment normally operated in both directions must be equipped with headlights for both directions

f. Service brakes that act on each wheel of the vehicle and that are designed such that failure of any single component, except the brake actuation pedal or other similar actuation device, must not result in a complete loss of service braking capability

g. Service brakes that safely bring the fully loaded vehicle to a complete stop on the maximum grade on which it is operated

h. No device that traps a column of fluid to hold the brake in the applied position shall be installed in any brake system, unless the trapped column of fluid is released when the equipment operator is no longer in contact with the brake activation device

3. Self-propelled non-permissible heavy-duty diesel-powered equipment under §75.1908(1), except rail-mounted equipment, shall be provided with a supplemental braking system that:

a. Engages automatically within 5 seconds of the shutdown of the engine

b. Safely brings the equipment when fully loaded to a complete stop on the maximum grade on which it is operated

c. Holds the equipment stationary, despite any contraction of brake parts, exhaustion of any non-mechanical source of energy, or leakage

d. Releases only by a manual control that does not operate any other equipment function

e. Has a means in the equipment operator's compartment to apply the brakes manually without the engine operating, and a means to release and reengage the brakes without the engine operating

f. Has a means to ensure that the supplemental braking system is released before the equipment can be trammed and is designed to ensure the brake is fully released at all times while the equipment is trammed.

4. Self-propelled non-permissible light-duty diesel-powered equipment under §75.1908(2), except rail-mounted equipment, must be provided with a

parking brake that holds the fully loaded equipment stationary on the maximum grade on which it is operated despite any contraction of the brake parts, exhaustion of any non-mechanical source of energy, or leakage.

5. The supplemental and park brake systems required by paragraphs (3) and (4) must be applied when the equipment operator is not at the controls of the equipment, except during movement of disabled equipment.

6. Self-propelled personnel-elevating work platforms must be provided with a means to ensure that the parking braking system is released before the equipment can be trammed and must be designed to ensure the brake is fully released at all times while the equipment is trammed.

7. Any non-permissible equipment that discharges its exhaust directly into a return air course must be provided with a power package approved under subpart F of part 7 of this title.

8. Self-propelled non-permissible heavy-duty diesel-powered equipment meeting the requirements of §75.1908(a) must be provided with an automatic fire suppression system meeting the requirements of §75.1911.

9. Self-propelled non-permissible heavy-duty diesel-powered equipment meeting the requirements of §75.1908(b) must be provided with an automatic or manual fire suppression system meeting the requirements of §75.1911.

10. Non-permissible equipment that is not self-propelled must have the following features in addition to those listed in paragraph (1):

a. A means to prevent inadvertent movement of the equipment when parked

b. Safety chains or other suitable secondary connections on equipment that is being towed

c. An automatic fire suppression system meeting the requirement of §75.1911.

§75.1910 Non-Permissible Diesel-Powered Equipment; Electrical System Design Band Performance Requirements

Electrical circuits and components associated with or connected to electrical systems on non-permissible diesel-powered equipment utilizing storage batteries and integral charging systems, except for the special category of equipment under §75.1908(d) must conform to the following requirements:

1. Overload and short circuit protection must be provided for electric circuits and components in accordance with §75.518 and §75.518-1 of this part

2. Each electric conductor from the battery to the starting motor must be protected against short circuit by fuses or other circuit-interrupting devices placed as near as practicable to the battery terminals

3. Each branch circuit conductor connected to the main circuit between the battery and charging generator must be protected against short circuit by fuses or other automatic circuit-interrupting devices.

4. The electrical system shall be equipped with a circuit-interrupting device by means of which all power conductors can be deenergized. The device must be located as close as practicable to the battery terminals and be designed to operate within its electrical rating without damage. The device shall not automatically reset after being actuated. All magnetic circuit-interrupting devices must be mounted in a manner to preclude their closing by force of gravity

5. Each motor and charging generator must be protected by an automatic overcurrent device. One protective device will be acceptable when two motors of the same rating operate simultaneously and perform virtually the same duty

6. Each ungrounded conductor must have insulation compatible with the impressed voltage. Insulation materials must be resistant to deterioration from engine heat and oil. Electric conductors must meet the applicable requirements of §75.513 and §75.513-1 except electric conductors for starting motors, which must only meet the requirements of §75.513

7. All wiring must have adequate mechanical protection to prevent damage to the cable that might result in short circuits

8. Sharp edges and corners must be removed at all points where there is a possibility of damaging wires, cables, or conduits by cutting or abrasion. The insulation of the cables within a battery box must be protected against abrasion

9. When insulated wires other than cables pass through metal frames, the holes must be substantially bushed with insulated bushings. Cables must enter metal frames of motors, splice boxes, and electric components only through proper fittings. All electrical connections and splices must be mechanically and electrically efficient, and suitable connectors shall be used. All electrical connectors or splices in insulated wire must be reinsulated at least to the same degree of protection as the remainder of the wire

10. The battery must be secured to prevent movement and must be protected from external damage by position. Batteries that are not protected from external damage by position must be enclosed in the battery box. Flame-resistant insulation treated to resist chemical reaction to electrolyte must be provided on battery connections to prevent battery terminals from contacting conducting surfaces

11. A battery box, including the cover, must be constructed of steel with a minimum thickness of 1/8 inch, or of a material other than steel that provides equivalent strength

12. Battery-box covers must be lined with a flame-resistant insulating material permanently attached to the underside of the cover, unless equivalent protection is provided. Battery-box covers must be provided with a means for securing them in closed position. At least ½ inch of air space must be provided between the underside of the cover and the top of the battery, including terminals

13. Battery boxes must be provided with ventilation openings to prevent the accumulation of flammable or toxic gases or vapors within the battery box. The size of locations of openings for ventilation must prevent direct access to battery terminals.

14. The battery must be insulated from the battery-box walls and supported on insulating materials. Insulating materials that may be subject to chemical reaction with electrolyte must be treated to resist such action.

15. Drainage holes must be provided in the bottom of each battery box.

§75.1911 Fire Suppression Systems for Diesel-Powered Equipment and Fuel Transportation Units

1. The fire suppression system required by §75.1907 and §75.1909 shall be a multipurpose dry chemical type (ABC) fire suppression system listed or approved by a nationally recognized independent testing laboratory and appropriate for installation on diesel-powered equipment and fuel transportation units.

a. The system shall be installed in accordance with the manufacturer's specifications and the limitations of the listing or approval.

b. The system shall be installed in a protected location or guarded to minimize physical damage from routine vehicle operations.

c. Suppressant agent distribution tubing or piping shall be secured and protected against damage, including pinching, crimping, stretching, abrasion, and corrosion.

d. Discharge nozzles shall be positioned and aimed for maximum fire suppression effectiveness. Nozzles shall also be protected against the entrance of foreign materials such as mud, coal dust, or rock dust.

2. The fire suppression system shall provide fire suppression and, if automatic, fire detection for the engine including the starter, transmission, hydraulic pumps and tanks, fuel tanks, exposed brake units, air compressors and battery areas on diesel-powered equipment and electric panels or controls used on fuel transportation units and other areas as necessary.

3. If automatic, the fire suppression system shall include audible and visual alarms to warn of fires or system faults.

4. The fire suppression system shall provide for automatic engine shutdown. If the fire suppression system is automatic, engine shutdown and discharge of suppressant agent may be delayed for a maximum of 15 seconds after the fire is detected by the system.

5. The fire suppression system shall be operable by at least two manual actuators. Once actuator shall be located on each side of the equipment. If the equipment is provided with an operator's compartment, one of the manual actuators shall be located in the compartment within reach of the operator.

6. The fire suppression system shall remain operative in the event of engine shutdown, equipment electrical system failure, or failure of any other equipment system.

7. The electrical components of each fire suppression system installed on equipment used where permissible electric equipment is required shall be permissible or intrinsically safe and such components shall be maintained in permissible or intrinsically safe condition.

8. Electrically operated detection and actuation circuits shall be monitored and provided with status indicators showing power and circuit continuity. If the system is not electrically operated, a means shall be proved to indicate the functional readiness status of the detection system.

9. Each fire suppression system shall be tested and maintained in accordance with the manufacturer's recommended inspection and maintenance program and as required by the nationally recognized independent testing laboratory listing or approval and be visually inspected at least once each week by a person trained to make such inspections.

10. Recordkeeping:

a. Persons performing inspections and tests of fire suppression systems under paragraph (I) shall record when a fire suppression system does not meet the installation or maintenance requirements of this section.

b. The record shall include the equipment on which the fire suppression system did not meet the installation or maintenance requirements of this section, the defect found, and the corrective action taken.

c. Records are to be kept manually in a secure manner not susceptible to alteration or recorded electronically in secured computer system that in not susceptible to alteration.

d. Records shall be maintained at a surface location at the mine for one year and made available for inspection by an authorized representative of the Secretary and miners' representatives.

11. All miners normally assigned to the active workings of the mine shall be instructed about the hazards inherent to the operation of the fire suppression systems and, where appropriate, the safeguards available for each system.

12. For purposes of §75.380(f), a fire suppression system installed on diesel-powered equipment and meeting the requirements of this section is equivalent to a fire suppression system meeting the requirements of §75.1107-3 through §75.1107-16.

§75.1912 Fire Suppression Systems for Permanent Underground Diesel Fuel Storage Facilities

1. The fire suppression system required by §75.1903 shall be an automatic multipurpose dry chemical type (ABC) fire suppression system listed or approved as an engineered dry chemical extinguishing system by a nationally recognized independent testing laboratory and appropriate for installation at a permanent underground diesel fuel storage facility.

a. Alternate types of fire suppression systems shall be approved in accordance with §75.1107-13 of this part.

b. The system shall be installed in accordance with the manufacturer's specifications and the limitations of the listing or approval.

c. The system shall be installed in a protected location or guarded to prevent physical damage from routine operations.

d. Suppressant agent distribution tubing or piping shall be secured and protected against damage, including pinching, crimping, stretching, abrasion, and corrosion.

e. Discharge nozzles shall be positioned and aimed for maximum fire suppression effectiveness in the protected areas. Nozzles must also be protected against the entrance of foreign materials such as mud, coal dust, and rock dust.

2. The fire suppression system shall provide automatic fire detection and automatic fire suppression for all areas within the facility.

3. Audible and visual alarms to warn of fire or system faults shall be provided at the protected area and at a surface location which is continually monitored by a person when personnel are underground. In the event of a fire, personnel shall be warned in accordance with the provisions set forth in §75.1101-23.

4. The fire suppression system shall deenergize all power to the diesel fuel storage facility when actuated except that required for automatic enclosure and alarms.

5. Fire suppression systems shall include two manual actuators located as follows:
   a. At least one within the fuel storage facility

   b. At least one a safe distance away from the storage facility and located in intake air, upwind of the storage facility.

6. The fire suppression system shall remain operational in the event of electrical system failure.

7. Electrically operated detection and actuation circuits shall be monitored and provided with status indicators showing power and circuit continuity. If the system is not electrically operated, a means shall be provided to indicate the functional readiness status of the detection system.

8. Each fire suppression system shall be tested and maintained in accordance with the manufacturer’s recommended inspection and maintenance program and as required by the nationally recognized independent testing laboratory listing or approval and be visually inspected at least once each week by a person trained to make such inspections.

9. Recordkeeping:
   a. Persons performing inspections and tests of fire suppression system does not meet the installation or maintenance requirements of this section.

b. The record shall include the facility whose fire suppression system did not meet the installation or maintenance requirements of this section, the defect found, and the corrective action taken.

c. Records are to be kept manually in a secure manner not susceptible to alteration or recorded electronically in a secured computer system that is not susceptible to alteration.

d. Records shall be maintained at a surface location at the mine for one year and made available for inspection by an authorized representative of the Secretary and miners' representatives.

10. All miners normally assigned to the active workings of the mine shall be instructed about the hazards inherent to the operation of the fire suppression systems and, where appropriate, the safeguards available for each system.

§75.1913 Starting Aids

1. Volatile fuel starting aids shall be used in accordance with recommendations provided by the starting aid manufacturer, the engine manufacturer, and the machine manufacturer.

2. Containers of volatile fuel starting aids shall be conspicuously marked to indicate the contents. When not in use, containers of volatile fuel starting aids shall be stored in metal enclosures that are used only for storage of starting aids. Such metal enclosures must be conspicuously marked, secured, and protected from damage.

3. Volatile fuel starting aids shall not be:

a. Taken into or used in areas where permissible equipment is required

b. Used in the presence of open flames or burning flame safety lamps, or when welding or cutting is taking place

c. Used in any area where 1.0 percent or greater concentration of methane is present.

4. Compressed oxygen or compressed flammable gases shall not be connected to diesel air-start systems.

§75.1914 Maintenance of Diesel-Powered Equipment

1. Diesel-powered equipment shall be maintained in approved and safe condition or removed from service.

2. Maintenance and repairs of approved features and those features required by §75.1909 and §75.1910 on diesel-powered equipment shall be made only by a person qualified under §75.1915.

3. The water scrubber system on diesel-powered equipment shall be drained and flushed, by a person who is trained to perform this task, at least once on each shift in which the equipment is operated.

4. The intake air filter on diesel-powered equipment shall be replaced or serviced, by a person who is trained to perform this task, when the intake air pressure drop device so indicates or when the engine manufacturer's maximum allowable air pressure drop level is exceeded.

5. Mobile diesel-powered equipment that is to be used during a shift shall be visually examined by the equipment operator before being placed in operation. Equipment defects affecting safety shall be reported promptly to the mine operator.

6. All diesel-powered equipment shall be examined and tested weekly by a person qualified under §75.1915.
    a. Examinations and tests shall be conducted in accordance with approved maintenance manuals.

    b. Persons performing weekly examinations and tests of diesel-powered equipment under this paragraph shall make a record when the equipment is not in approved or safe condition. This record shall include the equipment that is not in approved or safe condition, the defect found, and the corrective action taken.

7. Undiluted exhaust emissions of diesel engines in diesel-powered equipment approved under part 36 and heavy-duty non-permissible diesel-powered equipment as defined in §75.1908(a) in use in underground coal mines shall be tested and evaluated weekly by a person who is trained to perform this task. The mine operator shall develop and implement written standard operating procedures for such testing and evaluation that specify the following:

a. The method of achieving a repeatable loaded engine operating condition for each type of equipment

b. Sampling and analytical methods (including calibration of instrumentation) that are capable of accurately detecting carbon monoxide in the expected concentrations

c. The method of evaluation and interpretation of the results

d. The concentration or changes in concentration of carbon monoxide that will indicate a change in engine performance. Carbon monoxide concentration shall not exceed 2500 parts per million

e. The maintenance of records necessary to track engine performance.

8. Recordkeeping: Records required by paragraphs (6) (b) and (7) (5) shall be:

a. Recorded in a secure book that is not susceptible to alteration, or recorded electronically in a computer system that is secure and not susceptible to alteration

b. Retained at a surface location at the mine for at least 1 year and made available for inspection by an authorized representative of the Secretary and by miners' representatives.

i. Diesel-powered equipment must be maintained in accordance with this part as of November 25, 1997.

§75.1915 Training and Qualification of Persons Working on Diesel-Powered Equipment

1. To be qualified to perform maintenance, repairs, examinations and tests on diesel-powered equipment, as required by §75.1914, a person must successfully complete a training and qualification program that meets the requirements of this section. A person qualified to perform these tasks shall be retrained as necessary to maintain the ability to perform all assigned diesel-powered equipment maintenance, repairs, examinations and tests.

2. A training and qualification program under this section must:

a. Be presented by a competent instructor

b. Be sufficient to prepare or update a person's ability to perform all assigned tasks with respect to diesel-powered equipment maintenance, repairs, examinations, and tests

c. Address, at a minimum, the following:
    i. The requirements of subpart T of this part
    ii. Use of appropriate power package or machine checklists to conduct tests to ensure that diesel-powered equipment is in approved and safe condition, with acceptable emission levels
    iii. Proper maintenance of approved features and the correct use of the appropriate maintenance manuals, including machine adjustments, service, and assembly
    iv. Diesel-powered equipment fire suppression system tests and maintenance
    v. Fire and ignition sources and their control or elimination, including cleaning of the equipment
    vi. Safe fueling procedures and maintenance of the fuel system of the equipment
    vii. Intake air system maintenance and tests.

d. Include an examination that requires demonstration of the ability to perform all assigned tasks with respect to diesel-powered equipment maintenance, repairs, examinations and tests

e. Be in writing. The written program shall include a description of the course content, materials, and teaching methods for initial training and retraining

3. Recordkeeping:

a. The operator shall maintain a copy of the training and qualification program required by this section and a record of the names of all persons qualified under the program.

b. The record of the names of qualified persons shall be made in a manner that is not susceptible to alteration or recorded electronically in a computer system that is secure and not susceptible to alteration.

c. The training and qualification program and record of qualified persons are to be kept at surface location of the mine and made available for inspection by an authorized representative of the Secretary and by miners' representatives.

§75.1916 Operation of Diesel-Powered Equipment

1. Diesel-powered equipment shall be operated at a speed that is consistent with the type of equipment being operated, roadway conditions, grades, clearances, visibility, and other traffic.

2. Operators of mobile diesel-powered equipment shall maintain full control of the equipment while it is in motion.

3. Standardized traffic rules, including speed limits, signals and warning signs, shall be established at each mine and followed.

4. Except as required in normal mining operations, mobile diesel-powered equipment shall not be idled.

5. Diesel-powered equipment shall not be operated unattended.

VI. Federal Regulations Sample Questions

Q. A facility constructed to remain at one location for the storage and dispensing of diesel fuel is:
A. A permanent underground diesel fuel storage facility.

Q. Safety cans and diesel fuel tanks can be used underground to store:
A. Diesel fuel

Q. One temporary underground diesel fuel storage area is allowed:
A. Within 500 feet of a loading point for each working section

Q. Permanent and temporary underground diesel fuel storage areas must be:
A. At least 25 feet from power cables or electric equipment.

Q. Who approves diesel engines for use in underground coal mines?
A. The Mine Safety and Health Administration (MSHA).

Q. Emergency device to shut off air supply and a flame arrestor are included in:
A. The diesel engine intake system.

Q. Exhaust discharge temperature must be limited to:
A. 170 degrees Fahrenheit (F) for wet and 302 degrees (F) for dry.

Q. The MSHA approval plate for an individual unit of diesel-powered equipment will contain:
A. The minimum ventilating air quantity required

Q. What safety feature should the intake air system be equipped with?
A. Intake air shut off valve and intake flame arrestor

Q: What are the two categories of diesel engines?
A: Category A engines and Category B engines.

Q: What is a Category A engine?
A: Permissible Diesel engine.

Q: What is a Category B engine?
A: Non-permissible Diesel engine.

Q: The temperature of any external surface of the diesel power package shall not exceed:
A: 302°F (150 °C).

Q: The exhaust gas temperature at discharge from a wet exhaust conditioner before the exhaust gas is diluted with air shall not exceed
A: 170°F (76°C).

Q: The fuel injection system shall be constructed that the quantity of fuel injected shall be arranged that this adjustment can be changed only by:
A: Breaking a seal or unlocking a compartment.

Q: What shall be provided to ensure that only clean fuel will reach the injection pump or injectors?
A: Filters.

Q: The valve that is installed in the intake system that is operable from the operator's compartment, to shut off the air supply to the engine is called:
A: Air shutoff valve.

Q: The exhaust cooling system shall be capable of reducing the temperature of the undiluted exhaust gas to less than:
A: 170 degrees Fahrenheit at the point of discharge from the cooling system.

Q: Water-jacketed on exhaust systems shall had provisions made for positive circulation of water in the jackets and to automatically shut off the engine when:
A: The temperature in the cooling jacket(s) exceeds 212 degrees Fahrenheit.

Q: The minimum ventilating air quantity for an individual unit of diesel-powered equipment being operated shall be at least that specified on the:
A: Approval plate for that equipment.

Q: What is the minimum ventilating air quantity where multiple units of diesel-powered equipment are operated on working section?
A: At least the sum of that specified on the approval plates of all the diesel-powered equipment on the working section.

Q: What is the total capacity of stationary diesel fuel tanks in permanent underground diesel fuel storage facilities?
A: Not exceed 1000 gallons.

Q: How many temporary underground diesel fuel storage areas are permitted for each working section?
A: Only one (1).

Q: Safety fueling cans must be limited to a nominal capacity of:
A: 5 gallons or less

Q: Diesel fuel shall be transported only by:
A: Diesel fuel transportation units or in safety can

Q: Diesel fuel transportation units must transport no more than:
A: 500 gallons of diesel fuel at a time.

Q: Diesel fuel transportation units and vehicles transporting safety cans containing diesel fuel must have at least:
A: Two (2) multipurpose, dry chemical type (ABC) fire extinguishers.

Q: What is the maximum number of safety cans that can be transported on a vehicle at any time?
A: One (1)

Q: During the transportation of safety can, the can must be protected from:
A: Damage during transport.

Q: Where shall safety cans stored underground?
A: Permanent underground diesel fuel storage facilities.

Q: Volatile fuel starting aids shall not be used:
A: Where permissible equipment is required; in the presence of open flames; in any area where 1.0 percent or greater concentration of methane is present.

Q: The exhaust system of permissible engine shall be provided with:
A: Flame arrester to prevent propagation of flame or discharge of heated particles to a surrounding flammable mixture.

Q: All V-belts shall be static conducting and have a resistance not exceeding:
A: 6 megohms,

Q: The diesel power package shall be equipped with:
A: A safety shutdown system which will automatically shut off the fuel supply and stop the engine.

Q: An exhaust conditioner that cools the exhaust gas through direct contact with water is commonly called:
A: Water scrubber

Fletcher M3023-AD
Diesel Tram & Drill

UNIT VII

DIESEL PARTICUALATE MATTER

Diesel Particulate Matter

30 CFR Part 72
Sections 72.500 & 2.520

A. <u>Diesel Particulate Matter (DPM)</u>

Introduction:

The Federal Coal Mine Health and Safety Act of 1969, known as "The Coal Act" was signed into law by President Richard Nixon on December 30th, 1969. The law established new health and safety standards for the coal mining industry. The Bureau of Mines (already in existence since 1910 under the Department of the interior) was responsible for implementing some of the provisions of the new Coal Act. However, due to limitation in enforcement power, and with later legislation like the Mine Safety and Health Act of 1977, the Mine Safety and Health Administration (MSHA) was created within the Labor Department (by legislation) in 1978. In 1996 the USBM was abolished, and its functions were transferred to other agencies including MSHA.

On December 29th, 1970, President Richard Nixon also signed into law the Occupational Safety and Health Act, which was enacted on April 28, 1971. The "Act" established three permanent agencies:

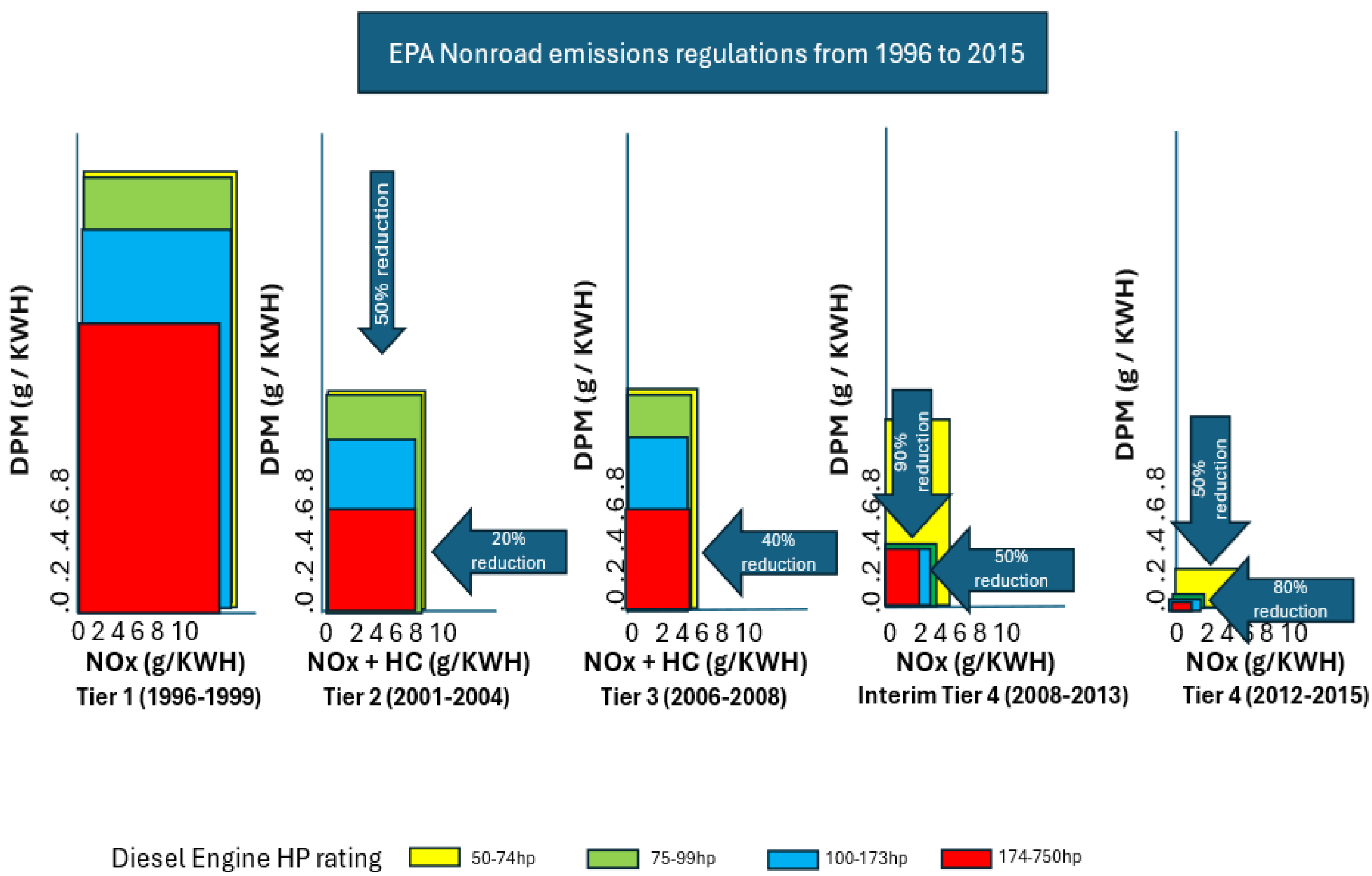
1. The Occupational Safety and Health Administration (OSHA)
2. The National Institute for Occupational Safety and Health (NIOSH)
3. The Occupational Safety and Health Review Commission (OSHRC).

The Clean Air Act (CAA) of 1970 was signed into law on December 31st, 1970 by President Richard Nixon as well. It became a federal law that regulated air emissions from all sources, including mobile and stationary sources. The CAA established the **U.S. Environmental Protection Agency (EPA)** and gave it the authority to regulate air pollutions. Among other air pollutants, the CAA addressed **particulate matter (PM, known as "soot") and Nitrogen oxide (NOx) which reacts with the atmosphere to create "smog".**

By the early 1980's, several governmental and private sector groups had started to identify specific health risk associated with prolonged exposure to high limits of Diesel Particulate Matter (DPM). OSHA (Occupational Safety and Health Administration) identified short term exposures risk to be associated with symptoms of headaches, dizziness, and respiratory system complications. OSHA and NIOSH identified long-term exposure to DPM as a key contributor to cardiovascular, cardiopulmonary and lung cancer. The Environmental Protection Agency (EPA) set forth restrictions on heavy-duty diesel trucks and buses in 1985. In 1998 the EPA set stricter standards for diesel engines used in nonroad equipment. In 2007 EPA standards for DPM limits went into place.

In 2008 the EPA required diesel particulate filters for all diesel trucks that weigh ¾ ton or more. In June of 2012 the International Agency for Research on Cancer (IARC) classified diesel particulate matter as a known human carcinogenic.

In an effort to reduce and control Particulate Matter and NOx emissions, the Clean Air Act allowed the EPA to establish and enforce rigorous emission requirements for all new non-road diesel engines starting in 1996. This is what we have come to know as the "Tier" emissions standards.



John Deer Agriculture, Residential and Construction Publication 2018

While diesel equipment used underground in coal mines is not directly subject to EPA tier emission standards, they are regulated and approved for use by the Mine Safety and Health Administration. Engines used must meet MSHA specific requirements for underground use, which often means stricter emission limits than standard Tier compliance, but those regulations do not necessarily align with the exact Tier system.

In 2001, MSHA promulgated more stringent emission limits for underground diesel equipment. 30 CFR Part 72 (72.500 -72.520) addressed specific requirements for Diesel Particulate Matter for all classifications of underground diesel-powered equipment. It also required that a diesel-powered inventory for all underground equipment be submitted to MSHA.

30CFR Part 72 (72.500 – 72.520)
Promulgated January 19, 2001

Purpose

- Established new health standards on DPM in underground coal mines.
- Reduced risks to underground coal miners from serious health hazards associated with exposure to DPM.
- Definition of the term “Introduced”
- Emission Limits: Permissible Equipment
- Emission Limits: Non-permissible Heavy-Duty Equipment, Generators, and Compressors
- Emission Limits: Non-permissible Light Duty Equipment
- Health Training
- Diesel Equipment Inventory
- Summary

B. §72.503(e) Definition of the term “introduced”

Equipment whose engine is a new addition to the underground inventory of the mine.

- Including:
  - Newly purchased equipment
  - Used equipment
  - Equipment receiving a replacement engine with a different serial number than the engine it is replacing
- Not Including:

- o Pieces of equipment whose engine was previously part of the mine inventory and rebuilt

C. Emission Limits: PERMISSIBLE Equipment Section 72.500(b)

- As of July 19th, 2022
- Each piece of permissible diesel equipment within the mine must emit no more than 2.5 grams per hour of diesel particulate matter

D. Emission Limits: Non-permissible Heavy-Duty Equipment, Generators, and Compressors Section 72.501(c)(d).

- As of January 19th, 2005
- Each piece within the mine must emit no more than 2.5 grams per hour of DPM
- Exceptions: A generator or compressor that discharges its exhaust directly into intake air that is coursed directly to a return air course or discharges its exhaust directly into a return air course is not subject to the applicable requirements of this section

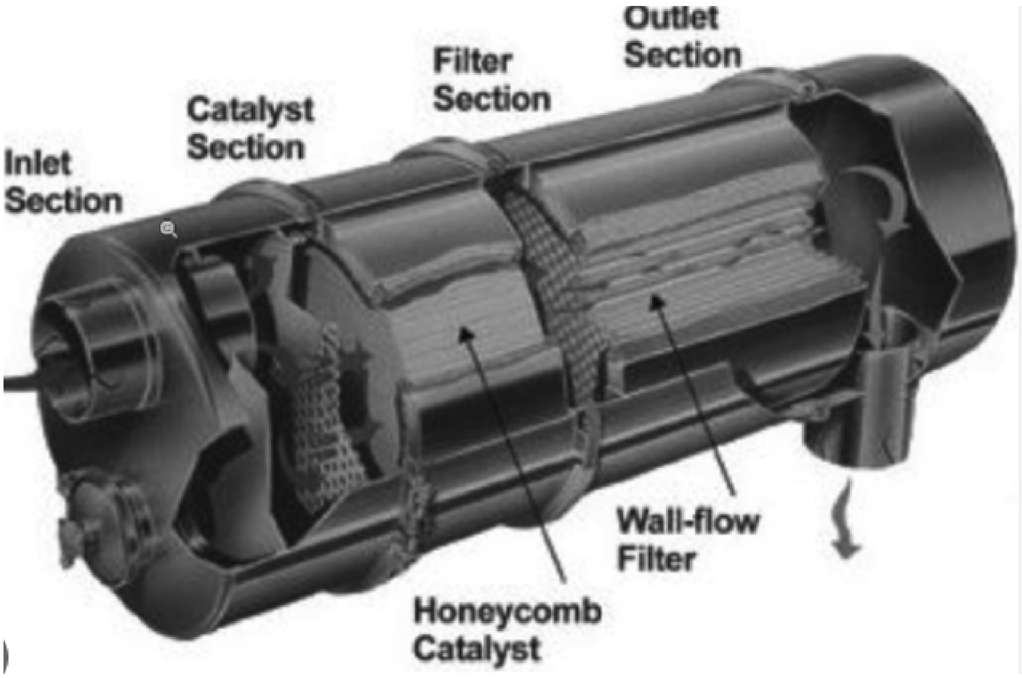
E. Emission Limits: Non-permissible Light-Duty Diesel Powered equipment Section 72.502(a)(c)

- **As of May 21,2001**
- Each piece of underground diesel equipment, other than generators and compressors, introduced into an underground mine must emit no more than 5.0 grams of diesel particulate matter.
- Exceptions: Does not apply to any diesel-powered ambulance or firefighting equipment that is used in accordance with the mine's fire-fighting and evacuation plans.

F. Emissions and Filter Selection Compliance Determination Example: Permissible Equipment @ 2.5 gm/hr

With the introduction of the DPM requirements of 2001, many existing machines already in use in underground coal mines, had to be retrofitted with Diesel Particulate Filters to meet compliance requirements. Listed below is an example of how aftermarket filter efficiency was calculated for an individual machine.

- For permissible machines, the baseline DPM emissions from a Category A diesel engine are multiplied by a filter efficiency to determine compliance.
- Reducing the horsepower rating of an approved engine in order to reduce the emissions would have required the engine to be retested at this reduced horsepower.



DPM paper filter assembly

Calculating Filter Efficiency for Permissible machine compliance.

Listed below are 2 examples of how DPM filter efficiency is calculated. After filter efficiency is calculated, an approved filter meeting the applicable efficiency would be installed on the existing machine to meet compliance requirements.

MSHA Approved Diesel Engines / Filter Efficiency
Engines for **Permissible Machines**

Approval Number	Manufacturer	Engine Model * Meets EPA	Rated Horse Power	PI CFM	DPM g/hr Weighted Average	Weighted Avg. Horsepower	DPM gr/bhp-hr	Filter Efficiency to obtain 5.0 gr/hr	Filter Efficiency to obtain 2.5 gr/hr
A001	Duetz	MWM916	94	15,000	25.49	51.1	0.50		90.2
A002	Caterpillar	3306 PCNA	150	27,000	45.88	87.2	0.53		94.6
A003	Caterpillar	3304 PCNA	100	17,500	29.74	58.1	0.51		91.6
A004	Isuzu	QD 100-306	66	10,000	16.99	38.3	0.44		85.3

Compliance Determination Example

- Caterpillar 3306PCNA diesel engine produces 45.88 gm/hr of DPM emission based on engine approval data.
- A paper filter has a DPM efficiency removal of 95%
- 45.88 gm/hr X 0.05 = 2.29 gm/hr

Compliance Determination Example

- Duetz MWM 916-6 diesel engine produces 25.49 gm/hr of DPM emission based on MSHA engine approval data.
- An equivalent paper filter is given a DPM efficiency removal of 90.2%.
- 25.49 gm/hr X 0.098 = 2.49 gm/hr

The same procedure would be used for non-permissible heavy-duty machines with a maximum DPM allowance of 2.5 gr/hr.

For a non-permissible light duty machine, the process is the same, but a filter efficiency would be calculated to obtain a maximum DPM allowance below 5.0 gr/hr.

Additional DMP Filter Compliance Information

- **Visit https://arlweb.msha.gov/TECHSUPP/ACC/lists/00dpmctl.pdf for a 2024 updated list of approved DPM filters including Paper, Base metal, and platinum-based diesel Particulate Filters.**
- Any pre-treatment device(s) or additive(s) must meet the requirements of §72.503.
    - Pre-treatment devices/additives will be evaluated the same as aftertreatment devices
    - Effectiveness of the pre-treatment devices supported by testing and data.
- If no data is available, the final rule specifies test procedure in §72.503(b).
- If mine operators are planning on using aftertreatment devices other than DPM filters, MSHA should be consulted.
- MSHA's Office of Technical Support can assist on evaluation of data that mine operators obtain from vendors or other sources.
- The aftertreatment device must meet the minimum efficiency requirements for the category and application in which the piece of equipment is used.

G. Miner Health Training §72.510

1. Operators must provide **annual training** to all miners who can reasonably be expected to be exposed to DPM emissions. The training must include:
    a. Health risks from DPM exposure.
    b. Methods used in the mine to control DPM.
    c. Identification of personnel responsible for maintaining controls.
    d. Actions miners must take to ensure controls operate as intended.

2. An operator must keep a record of the training at the mine site for one year after completion of the training. The record may be kept elsewhere, if the record is immediately accessible from the mine site by electronic transmission.

H. Diesel Equipment Inventory §72.520

1. The operator of each mine that utilizes diesel equipment underground, shall prepare and submit in writing to the District Manager, an inventory of diesel equipment used in the mine. The inventory shall include the number and type of diesel-powered units used underground, including make and model of unit, type of equipment, make and model of engine, serial number of engine, brake horsepower rating of engine, emissions of engine in grams per hour or grams per brake horsepower / hour, approval number of engine, make and model of aftertreatment device (if required), serial number of aftertreatment device if available, and efficiency of aftertreatment device.

2. The mine operator shall make changes to the diesel equipment inventory as equipment or emission control systems are added, deleted or modified and submit revisions, to the District Manager within 7 calendar days.

3. If requested, the mine operator shall provide a copy of the diesel equipment inventory to the representative of the miners within 3 days of the request.

I. Summary

1. <u>Obtaining Compliance</u>
    a. Equip machine's engines with an approved DPM filter if necessary for compliance.

b. Most new equipment will utilize an engine that is already compliant or that already has a compliant DPM filter system installed. Many of the new Tier 4 engines may not require filtration at all.

c. When replacing a diesel engine or purchasing a new or rebuilt machine, use engines that meet or exceed specific MSHA emission limits.

d. Generators and Compressors: Exhaust discharged directly into the return or into intake air coursed directly to a return is not subject to the applicable requirement of this section.

2. Inventory

a. Keep required inventory listings for all underground diesel powered equipment up to date.

b. Use MSHA's on-line filing system to make changes to the inventory.

3. Training

a. Conduct required annual training with all employees and retain records for review by interested parties.

UNIT VIII
DIESEL FIRE SUPPRESSION

What is the Purpose of a Fire Suppression System?

- MSHA requires dry chemical fire suppression system be on all underground diesel-powered equipment.
- To provide additional fire protection on equipment so that in the event of a fire the system will suppress the fire in its incipient stages.
- If equipment is equipped with an automatic detection and actuation fire suppression system, the equipment will have around the clock protection.
- To protect the equipment from excessive fire damage.
- **PROTECT Miners from INJURY.**

Pre-Engineered Fire Suppression System Manufacturers

- ANSUL – Most Common
- AMEREX – Few UG Systems
- AFEX – Mostly M/NM Surface Operations

New Technology continues to bring forth improvements to all aspects of the mining industry; fire suppression systems included. While Virginia Energy does not support or promote any individual fire suppression system or manufacturer, ANSUL is the predominant system used in Virgina's underground coal mines.

At the time of this publication Ansul continues to update its product lines, including those that meet requirements for underground mining equipment. Please see the following information concerning recent and forthcoming changes to Ansul's automatic fire suppression systems.

NOTICE CONCERNING ANSUL SC-N DETECTION AND ACTUATOR PRODUCTS

ANSUL BULLETIN No. 6019

- SC-N product line to be discontinued in May of 2015.
- CHECKFIRE SC-N replacement parts to be available for a 7-year period only.
- Ansul to replace their SC-N product line with the CHECKFIRE 110 and 210 systems.
- CHECKFIRE SC-N systems can be used while OEM replacement parts are available.
- CHECKFIRE MP-N systems are not currently affected.

NOTICE CONCERNING ANSUL CHECKFIRE 110 AND 210 SYSTEMS FOR USE IN UNDERGROUND COAL MINING OPERATIONS

ANSUL BULLETIN No. 2016128A

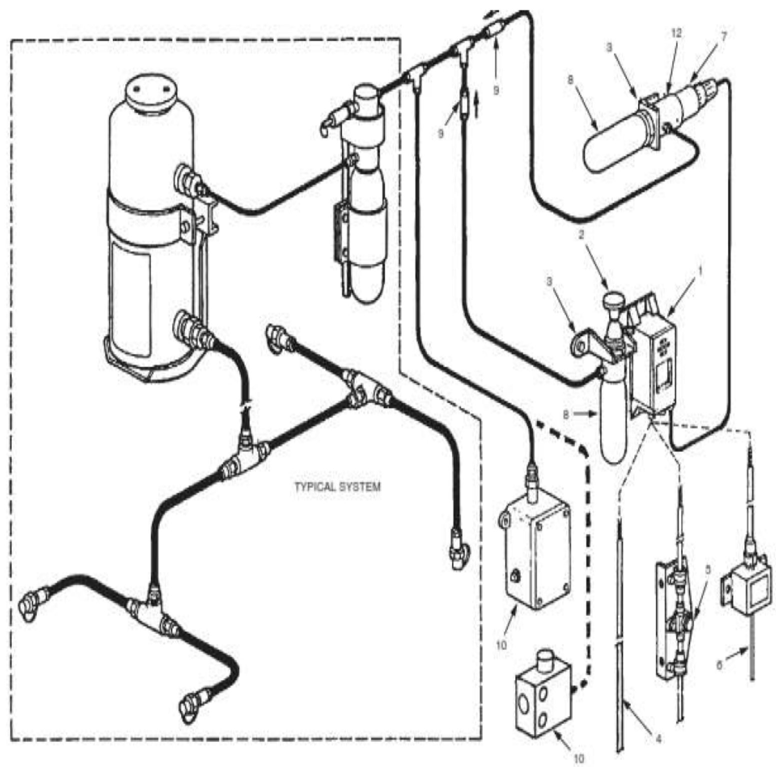
30 CFR 75.1911(f) The fire suppression system shall remain operative in the event of engine shutdown, equipment electrical system failure, or failure of any other equipment systems.
The ANSUL bulletin states:

- The Ansul CHECKFIRE 110 system does not comply with these requirements.
- The Ansul CHECKFIRE 210 system does comply with the requirements.

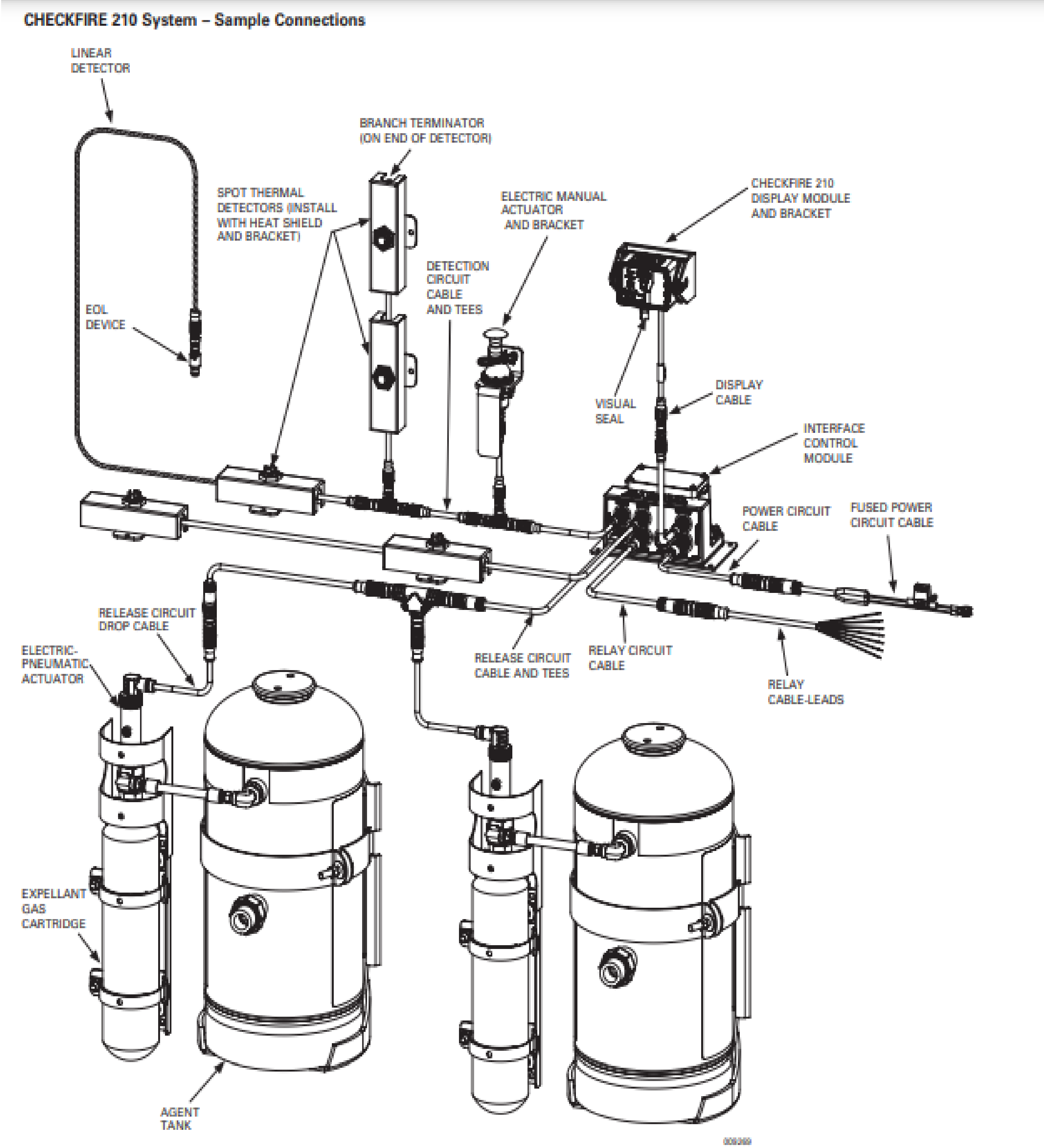
Ansul Basic System Layout- SC-N and MP-N systems

- **Checkfire M-PN system**

1. Control module.
2. Manual automatic actuator.
3. Mounting bracket.
4. Detection wire.
5. Thermal detectors.
6. Pneumatic linear detection.
7. Gas motor.
8. LT-10-R cartridge.
9. Check valve.
10. MSHA approved pressure switch (by others).
11. Test module (not shown).
12. Automatic actuator.



CHECKFIRE 210 System- Basic Layout



System Component Groups

- Detection and actuation
- Nozzles and distribution
- Dry chemical agent tank(s)

Detection and Actuation

- Actuation gas cartridge
- Manual actuator
- Squib
- Heat detection
- Linear detection wire, spot heat detection, and pneumatice detection

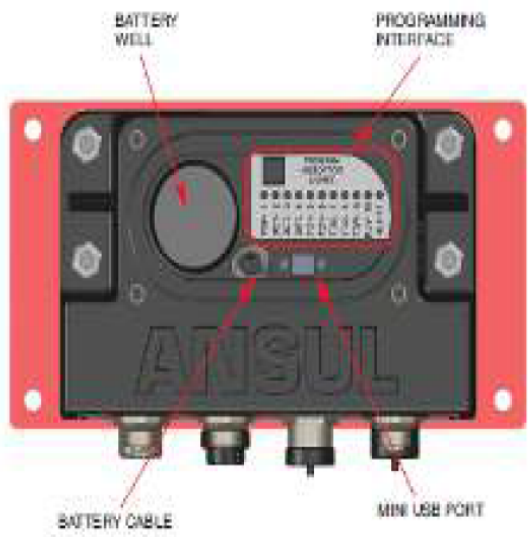
Control Module Equipment

CHECKFIRE 210 Control System

CHECKFIRE 210 Interface Control Module and Battery

Interface Control Module (ICM)

Cover removed to show battery compartment and programming interface.



ICM Battery Module

- 3.6 VDC Lithium Battery
- Connector pigtail connects ICM
- Located under battery compartment cover

Detection & Actuation

Electric Manual Actuator

Provides electrical system activation

- IP67 with fully potted electronics
- Supplied with rubber washer and nut
- Red strike button, rubber boot and ring pin common to current pneumatic manual actuator
- Installed in the Detection Circuit

CHECKFIRE SC-N Control Module

Manual Actuator SC-N/MP-N

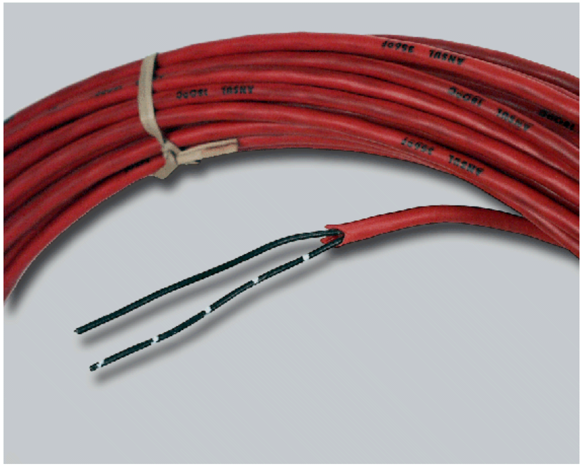
CHECKFIRE 210 Electric Actuator

Nitrogen Actuation Cartridge @ 900 psi

New Nitrogen Cartridge

Discharged Nitrogen Cartridge

Detection & Actuation

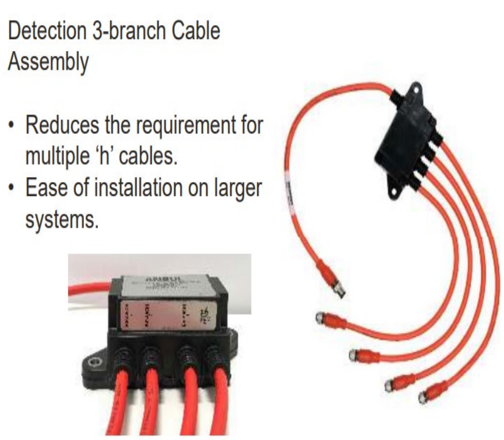


Linear Detection wire

Linear Detection Wire Melting Point 356° f

Thermal Spot Detectors

Pneumatic Detection



CHECKFIRE 210 – 3 Branch Cable Assembly

Non-Permissible Controller Unit

Suib
CHECKFIRE SC-N (Uses Squib)

Gas Motor
Permissible Controller Unit Check Fire MP-N
(Uses Gas Motor)

<u>Fire protection for diesel-powered equipment</u>:

- Mobile diesel-powered equipment shall have a multipurpose dry chemical type (ABC) fire suppression system or equivalent approved system.
- Nozzles placed to provide maximum protection to the fuel tank compartment, battery compartment, and hydraulic tanks.

Ansul SC-N Fire Suppression System

Control Interface ANSUL CHECKFIRE 210 System

Nozzles and Distribution

- Dry chemical
- Distribution hoses
- Triple tee
- Reducing tee
- Check valves
- Safety relief valve
- Nozzles

Reducing Tee

Triple Tee

Check Valves

Safety Relief Valve

C-1/2 Cone Nozzle

9.5 W Nozzle

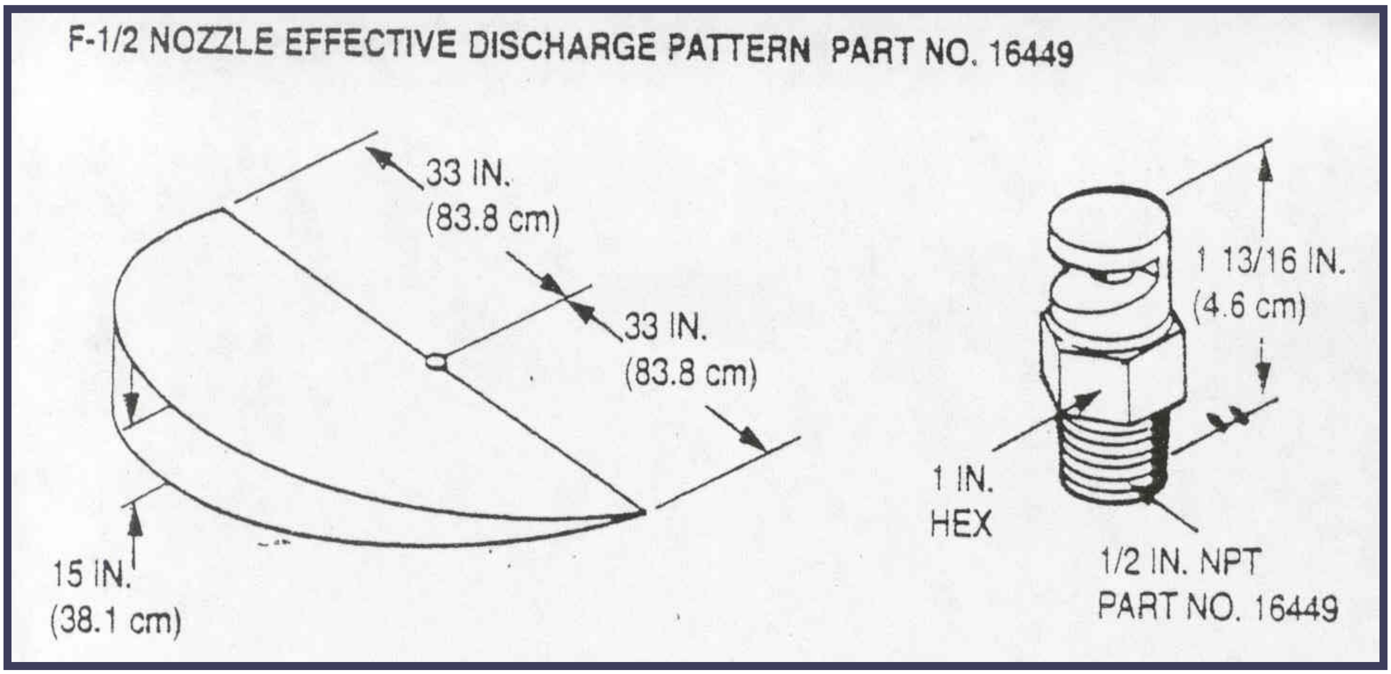
V-1/2 & C-1/2 Nozzles

Common Nozzle Types

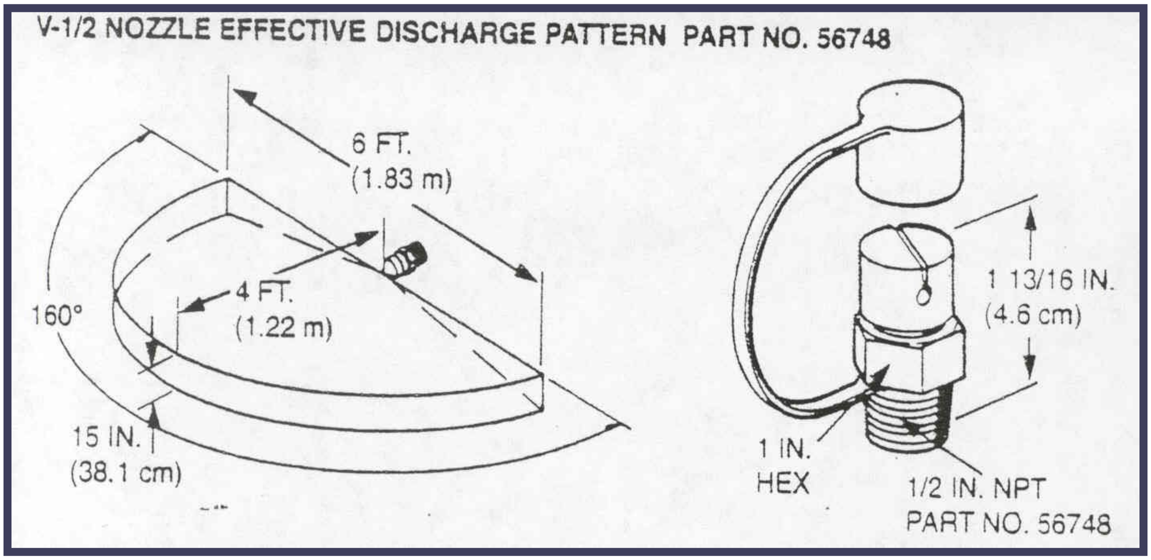
- F-1/2 FAN SPRAY
- V-1/2 FAN SPRAY
- C-1/2 CONE SPRAY

Note: Ansul offers several types of nozzles, but the above listed nozzles are used specifically for the A-101 pre-engineered suppression systems.

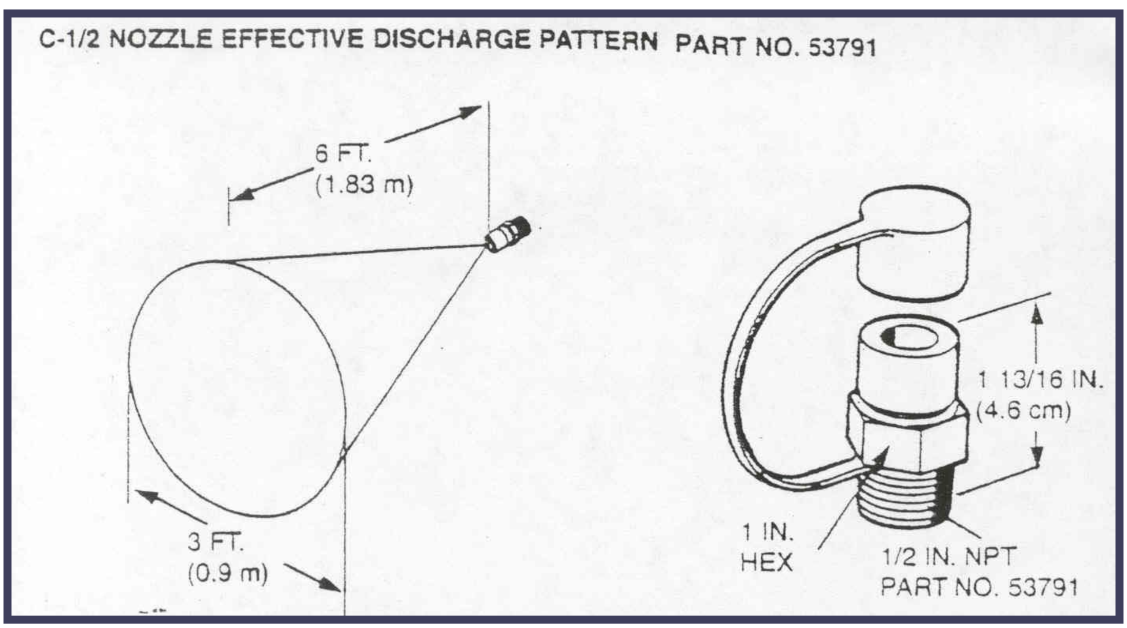
F-1/2 Fan Spray Nozzle



V-1/2 Fan Spray Nozzle

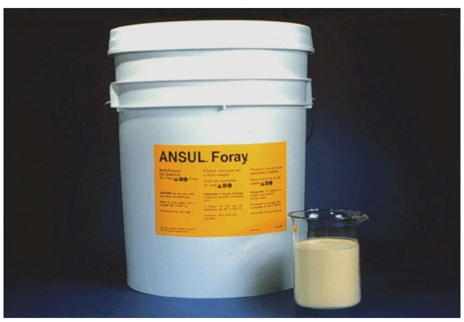


C-1/2 Cone Spray Nozzle



Dry Chemical Agent

- Dry chemical agent tank(s)
- Dry chemical Tank
- "ABC" dry chemical
- Burst disc
- Mounting brackets



Modes of Extinguishment

- **Absorb Heat**
- **Blocking radiative Energy Transfer**
- **Forms a surface coating – no O_2**
- **Disrupts Chemical Reaction Occurring in**
- **Fire**

Multipurpose, Monoammonium Phosphate, ABC, and Foray

Basic System Operation

1. Fire starts in protected area of diesel equipment.
2. The system is activated at a manual actuation point, or the fire is detected by the linear thermal sensing wire.
3. Nitrogen gas pressurizes the actuation line activating the pneumatic actuators at each dry chemical tank.
4. The pneumatic actuator pressurizes and fluidizes the dry chemical in the agent tank.
5. The agent tank burst disc ruptures allowing fluidized dry chemical to flow to each nozzle.

Proper System Installation

- Installation of the system shall be done in accordance with the manufacturers specifications
- Installation of the system should be done by the manufacturer of the system, or by a person who has been trained in the proper installation by the manufacturer.
- Installation manuals should be kept on the mine site as a reference guide for persons doing installation of the systems

Proper System Maintenance

- Proper suppression system maintenance should be performed to ensure the system will function correctly in the event of a fire
- The manufacturers maintenance schedule should be followed when performing maintenance on the fire suppression system
- Weekly visual examination must be performed and recorded on fire suppression systems
- A copy of the manufacture's maintenance manuals should be kept on the mine site for reference of proper system maintenance

Ansul a-101 vehicle fire suppression systems

> "*Maintenance shall be performed every 1000 hours or semi annually (whichever comes first). The fire suppression system including alarms, shutdown and associated equipment shall be thoroughly examined and checked for proper operation by the fire protection manufacturer, authorized distributor or their designee in accordance with the manual.*"
> (Ansul maintenance manual section viii, page 8-1)

Common Problems

Hoses not installed properly to prevent damage such as pinching, crimping, stretching, abrasion, and corrosion.

Nozzle Installation

1. Improper direction
2. Incorrect spray pattern
3. Not protected from damage
4. Object obstructing designed discharge pattern

Improper Check Valve Installation:

Check valves must be installed in proper direction – arrow points in direction of gas flow.

Improper Supply Line Installation:

Unbalanced system: the length of primary and secondary branch lines must be within 3:1 ratio.

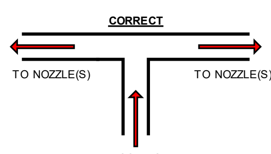
If system is discharged; supply lines must be cleaned of all dry chemical to prevent plugging of lines

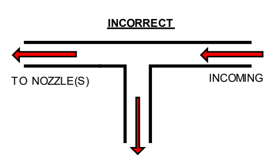
All nozzles must be protected from the entrance of mud, coal dust, or rock dust (f-1/2 nozzles can be filled with silicone grease in place of a dust cover)

The detection and actuation control module on automatic systems can be programmed with various alarm and shutdown delays. (§75.1911(d) requires that the system time from alarm to discharge shall not exceed 15 seconds)

Gas Motor Installation Correct

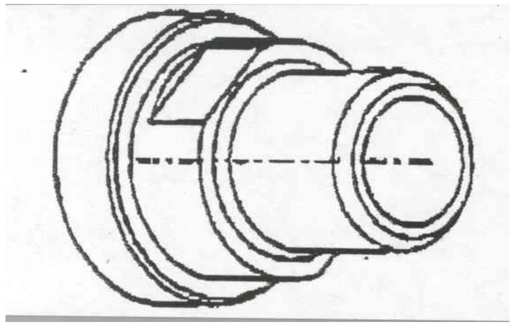
Gas Motor Installation Incorrect





In order to obtain equal distribution at a tee, the dry chemical must enter the tee at the center opening (bull)and exit the two side openings which are 180° apart.

System Changes



Ansul has designed a new burst disc assembly foruse on a-101 tanks (new burst disc assembly prevents operator error and prevents moisture from entering tank).

THE OLD-STYLE DISCS COULD POSSIBLY BE INSTALLED BACKWARDS

UNIT IX
DIESEL APPROVAL AND EMISSION

Approval for Use in Virginia Underground Coal Mines

When a Diesel Approval is requested, the following information should be in place prior to the approval visitation. Below is a sample approval form that will be used by Virginia Energy representatives during the diesel approval process.

Diesel Approval Form:

Company Name:		Mine Name or Number:			Mine Index Number:
Address:	Location:				MSHA ID Number:
City:	State:	Zip:	County:	Office Phone Number:	Mine Phone Number:
Person with Overall Responsibility:			Person in Charge of Health and Safety:		

Equipment Manufacturer: ______________________________

Type: ______________________________

MSHA Permissible Approval #: ___________ Power Package Approval # ___________

Model # ______________________ Serial # ______________________

Engine

Manufacturer ______________________ MSHA Cert. Approval # ___________

Model #: ______________________ Serial #: ______________________

Number of cylinders: ______________ Horsepower (HP): ______________

Ventilation Rate: ______________________________

Exhaust Treatment:

- ☐ Catalytic Converter
- ☐ Diffuser
- ☐ Scrubber
- ☐ Oxidation Catalytic Converter
- ☐ Particulate Filter
- ☐ Other ______________

Diesel Equipment Approval:

- ☐ Evaluation of undiluted exhaust emissions
- ☐ CO PPM ______________ RPM ______________
- ☐ Approved plan for stationary diesel-powered equipment
- ☐ Approved plan for diesel-powered portable generator

Operation of Diesel Equipment:

- ☐ Free of accumulations of coal dust, oil, grease, fuel and other combustible materials
- ☐ Audible warning device
- ☐ Engine start and stop mechanism
- ☐ Guards over moving components
- ☐ Re-railing device (self-propelled rail equipment only)
- ☐ Sanding devices (self-propelled rail equipment only)
- ☐ Headlights on each end

- ☐ Park and Service brakes
- ☐ Fire suppression system
- ☐ Intake and exhaust couplings in good condition
- ☐ Self-closing filler cap on fuel tank
- ☐ Trolley wire minimum clearance 6 inches or adequately insulated
- ☐ Engine shall not start unless transmission in neutral

Permissible Equipment

- ☐ Electrical component permissibility maintained
- ☐ Emergency engine shutdown operable
- ☐ Flame arrestors (intake and exhaust) provided
- ☐ Low-level shutdown (water bath/scrubber) operable

Maintenance of Diesel Equipment

- ☐ Hour meter reading: ______________________________
- ☐ Certified diesel mechanic
- ☐ Maintenance manuals available for review
- ☐ Record keeping process established

Ventilation of Diesel Equipment

- ☐ Evaluation of the adequacy of ventilation

Emission Testing and Evaluation

- ☐ Written procedures for weekly evaluation and test
- ☐ Repeatable load test method
- ☐ Sampling and analytical method to measure undiluted exhaust
- ☐ Instrumentation calibration
- ☐ Evaluation and interpretation of sampling results
- ☐ MSHA Engine Approval Data

  CO PPM: ____________________ RPM: ______________________

Fire Protection for Diesel-powered Equipment

- ☐ Mobile diesel-powered equipment fire suppression system
- ☐ Nozzles and reservoirs placed to provide maximum protection to the fuel tank compartment, battery compartment and hydraulic tanks
- ☐ Stationary diesel-powered equipment system AUTOMATIC fire suppression system

Fuel specifications

Statement from diesel fuel supplier

Date: _____________ Sulfur Content: ___________ Flash Point: ________________________

Comments:

Date Approved: ________________________________

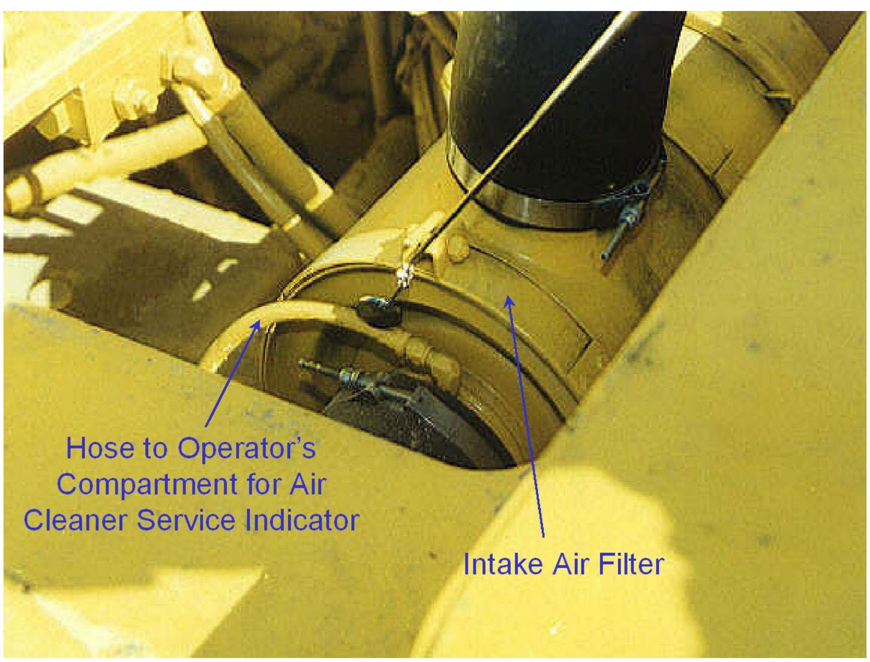
Inspector/Specialist: ________________________________

Requirement Information for Approval

Equipment: For outby equipment this information can usually be found on a tag somewhere near the operator's compartment. If not, review the maintenance manual. Permissible machines will have a MSHA Permissible Approval number. This can normally be found on an approval plate mounted to the machine.

Power Package Approval No.: 30 CFR Part 7.105-Each approved diesel power package shall be identified by a legible and permanent approval plate inscribed with and securely attached to the diesel power package in a manner that does not impair any explosion-proof characteristics (where applicable). The machine power package includes the engine, the intake and exhaust systems, and the safety shutdown system.

The intake system basically includes the intake air cleaner (filter) and intake duct work. On permissible machines an intake air shutoff valve and flame arrestor will be included. The exhaust system basically consists of the exhaust pipe connected to the engine exhaust manifold, DPM filter (where applicable), wet scrubber (where applicable), and exhaust outlet pipe. The safety component system consists of a temperature sensor used for monitoring the temperature of the engine cooling water and where applicable, an exhaust scrubber low water level shutdown valve. Also, machines equipped with an exhaust particulate filter may be equipped with a separate sensor to monitor the temperature of the exhaust gases as well as a back pressure gauge. The temperature sensor valve(s) automatically shut the engine down if a specified temperature is exceeded (170 degrees Fahrenheit exhaust gas or 212 degrees Fahrenheit coolant temperature).



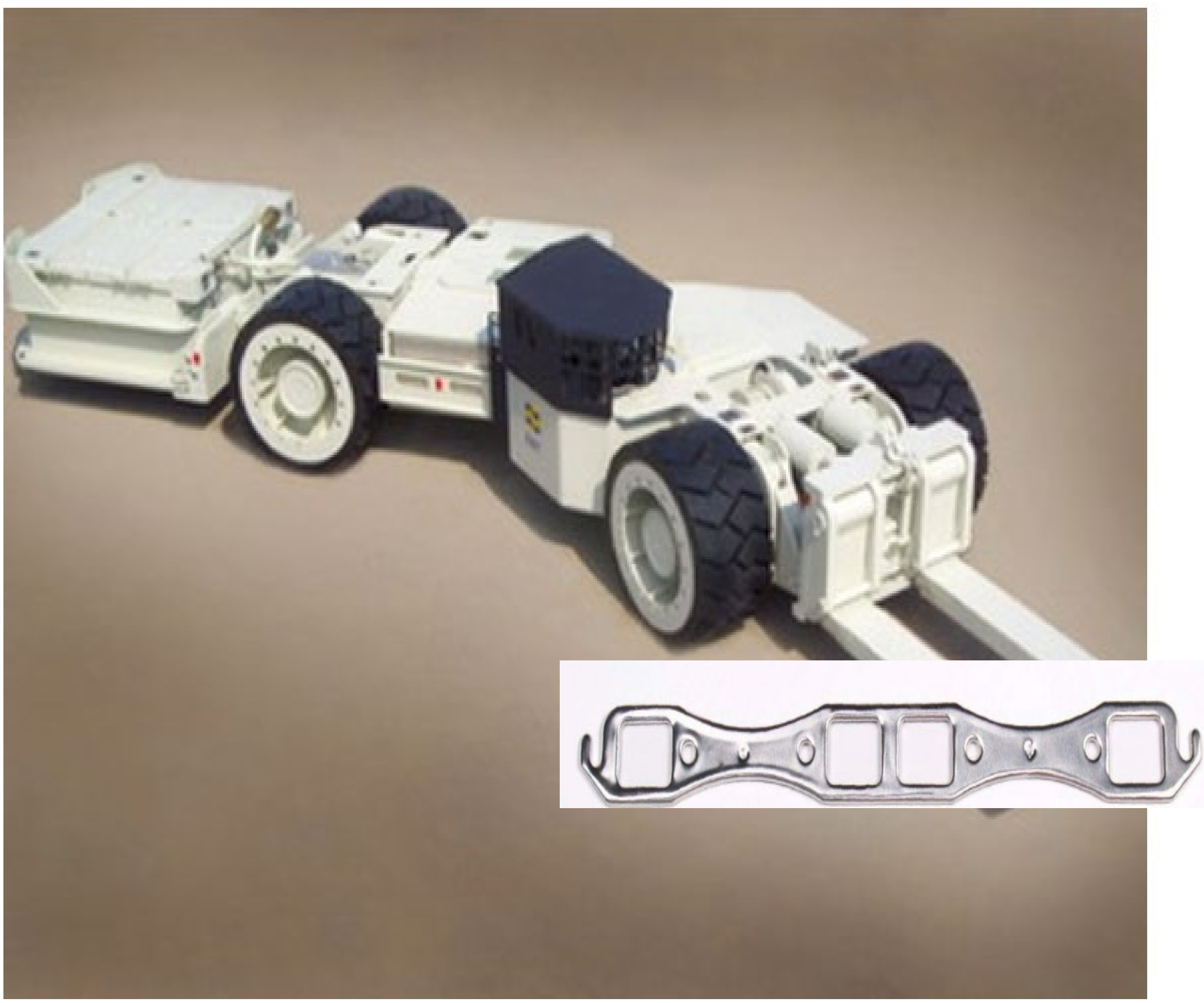
The power package of the machine must be checked at least weekly to ensure that it is being maintained in accordance with applicable requirements.

The power packages of permissible diesel machines are designed and constructed to guard against ignition of methane and coal dust by the hot engine and its components, surfaces, and by the internal combustion of the engine. A permissible machine is equipped with flame arresters on both the intake air and exhaust gas systems of the engine. The exhaust flame arrester on this machine is the water scrubber. The flame arresters quench flames that could be produced by an ignition of methane inside the engine, before the flames could propagate to an explosive environment. The portions of the intake and exhaust systems extending from the engine to the intake and exhaust flame arresters are manufactured and approved as explosion-proof and need to be maintained as such. Joints in these portions of these systems are secured with close tolerance fits and must be maintained. On permissible diesel machines, either flanged metal-to-metal joints or flanges fitted with metal or metal-clad gaskets are used. Some explosion-proof joints are equipped with metal-clad gaskets. All joints are to be secured tightly in place at all times using fasteners and lock washers, or other locking devices. Joints are to be checked weekly with appropriately sized feeler gauges.

The engine, and the intake and exhaust systems extending from the engine to the flame arrester and scrubber, are required to be explosion-proof and need to be maintained as such. This requires that joints formed in the connections of the various components be secured with close tolerance fits.

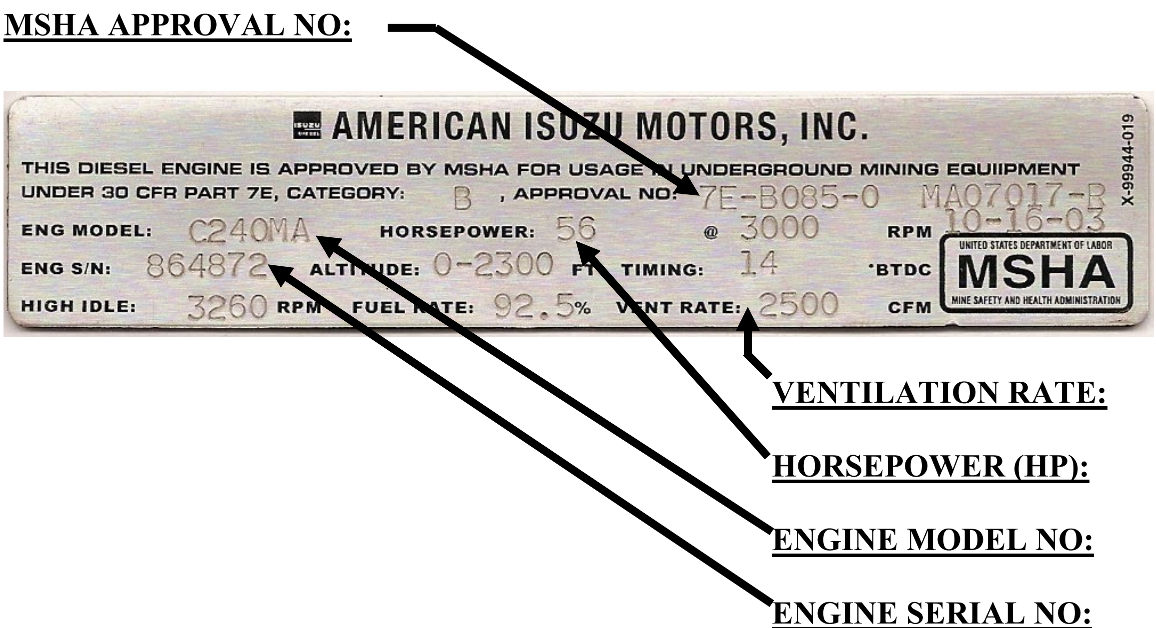
Examples of metal-clad gaskets

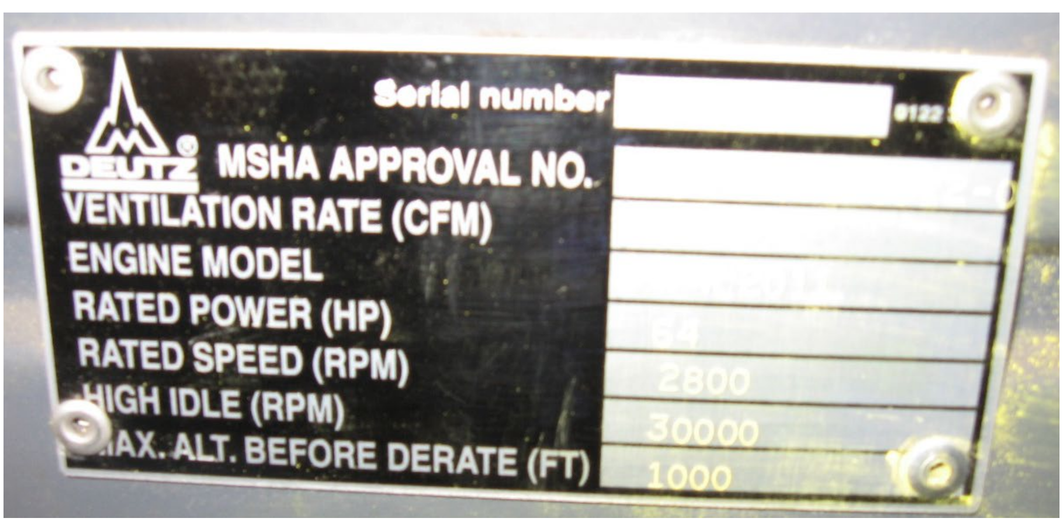
Cat 650 Shield Hauler



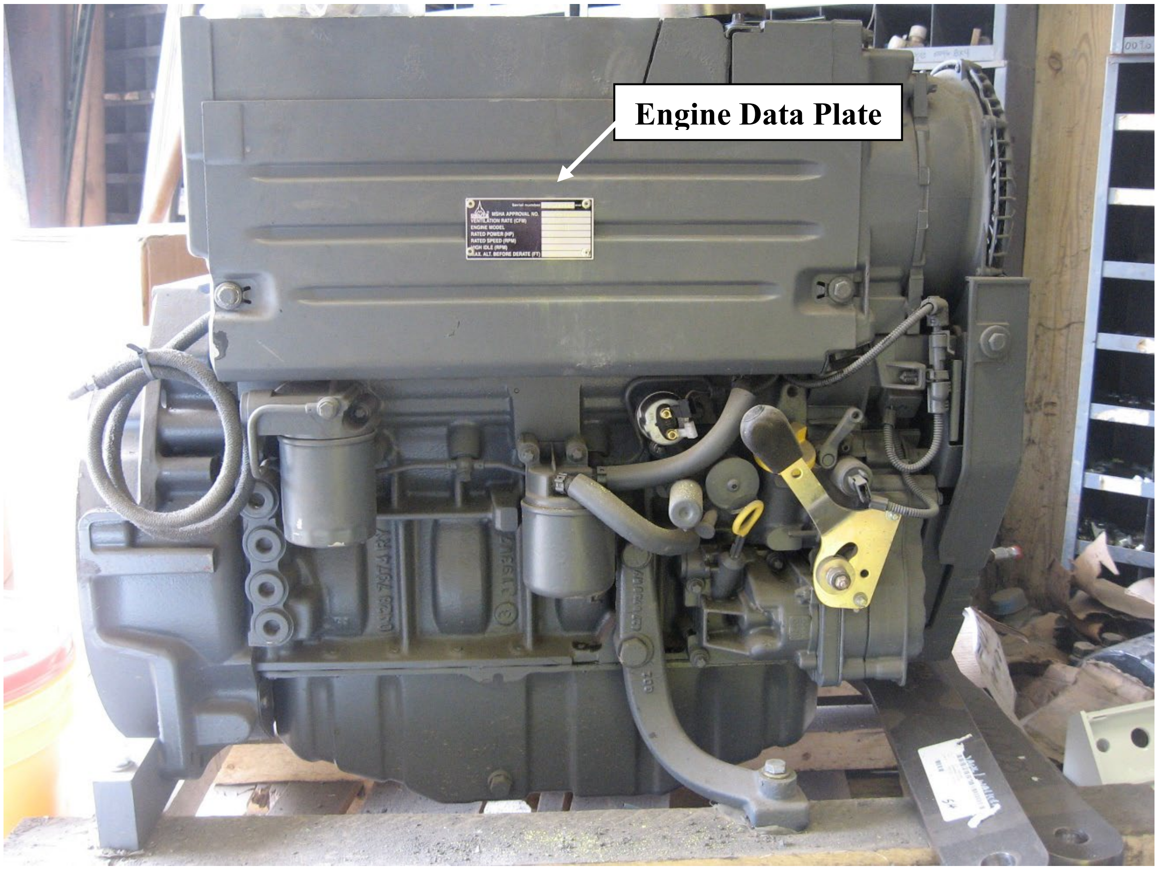
Engine Data: This information can be found on the MSHA Certification Tag attached to the engine. Sometimes a model number is not listed but is usually listed in the maintenance manual.

Typical Engine Data Plates



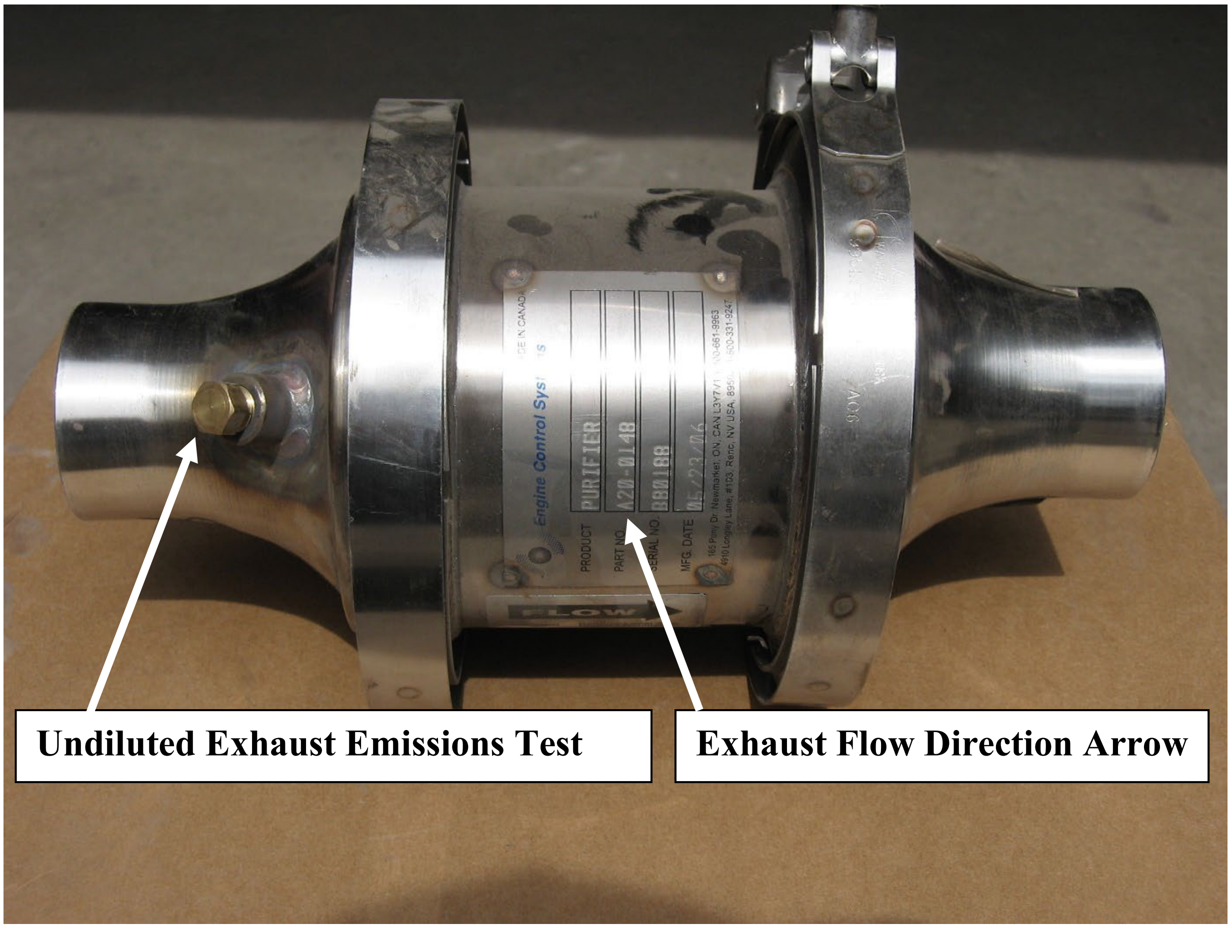


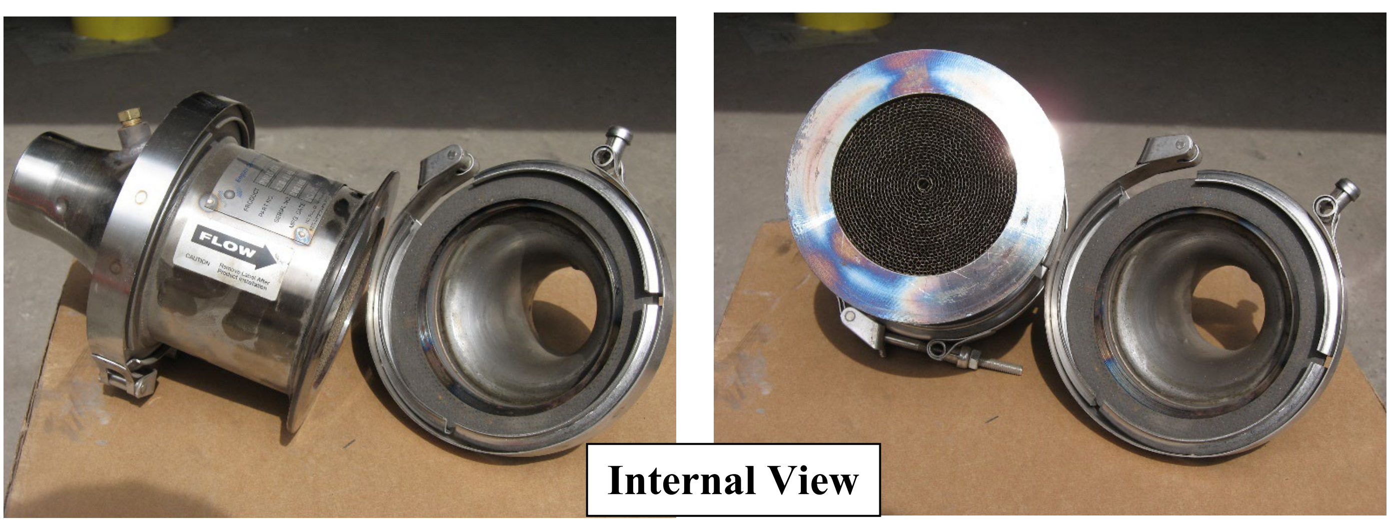
Deutz Diesel Engine
(F4L2011)



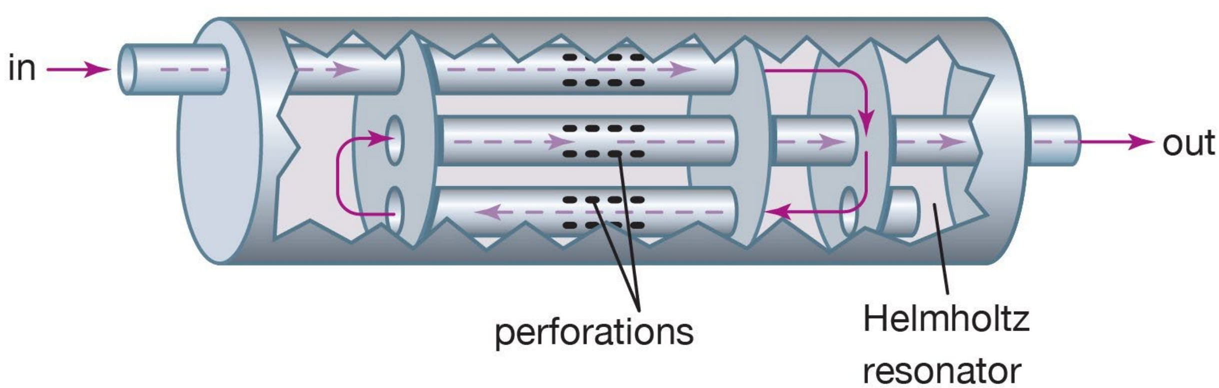
<u>Exhaust Treatment</u>: Shown below is a standard exhaust treatment device. A muffler is not an exhaust treatment device. An exhaust treatment device is some apparatus that dilutes or lowers DPM or emission levels.

<u>Typical Catalytic Converter</u>



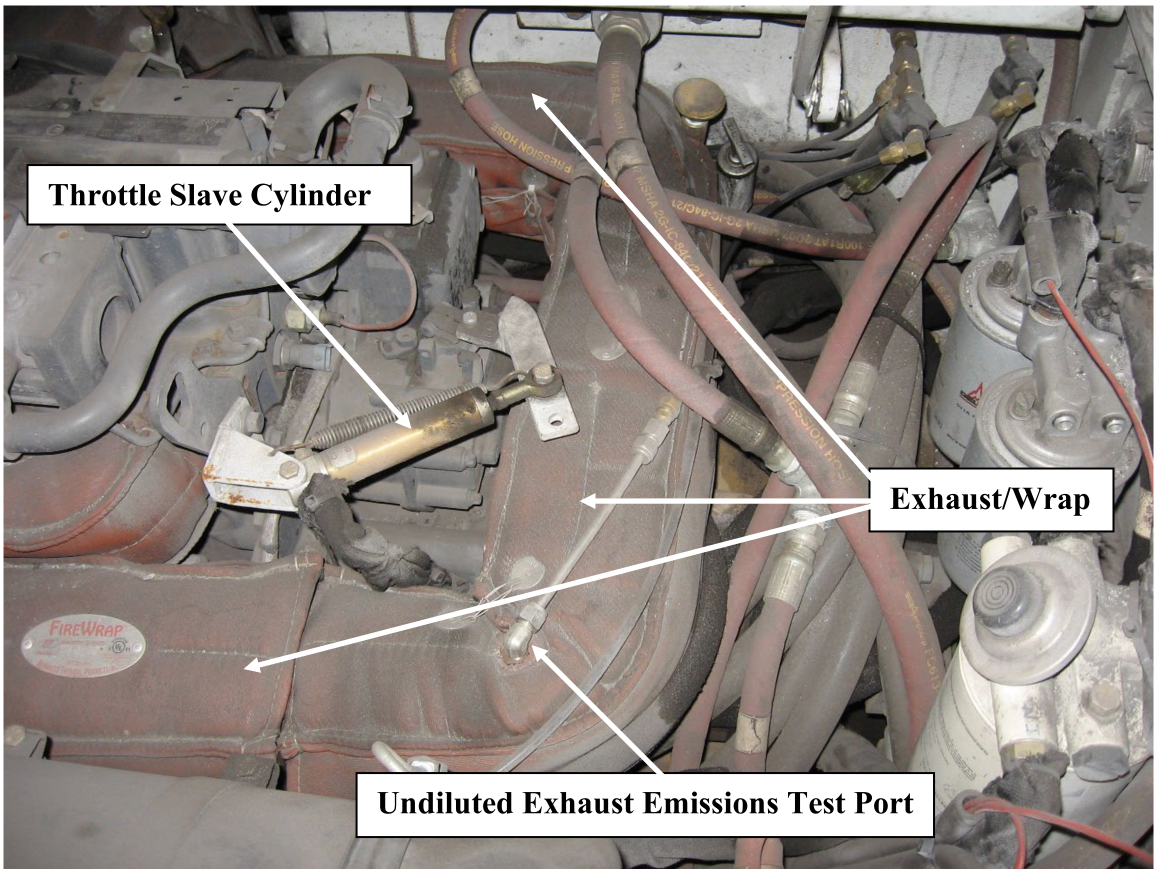


Typical Exhaust Muffler

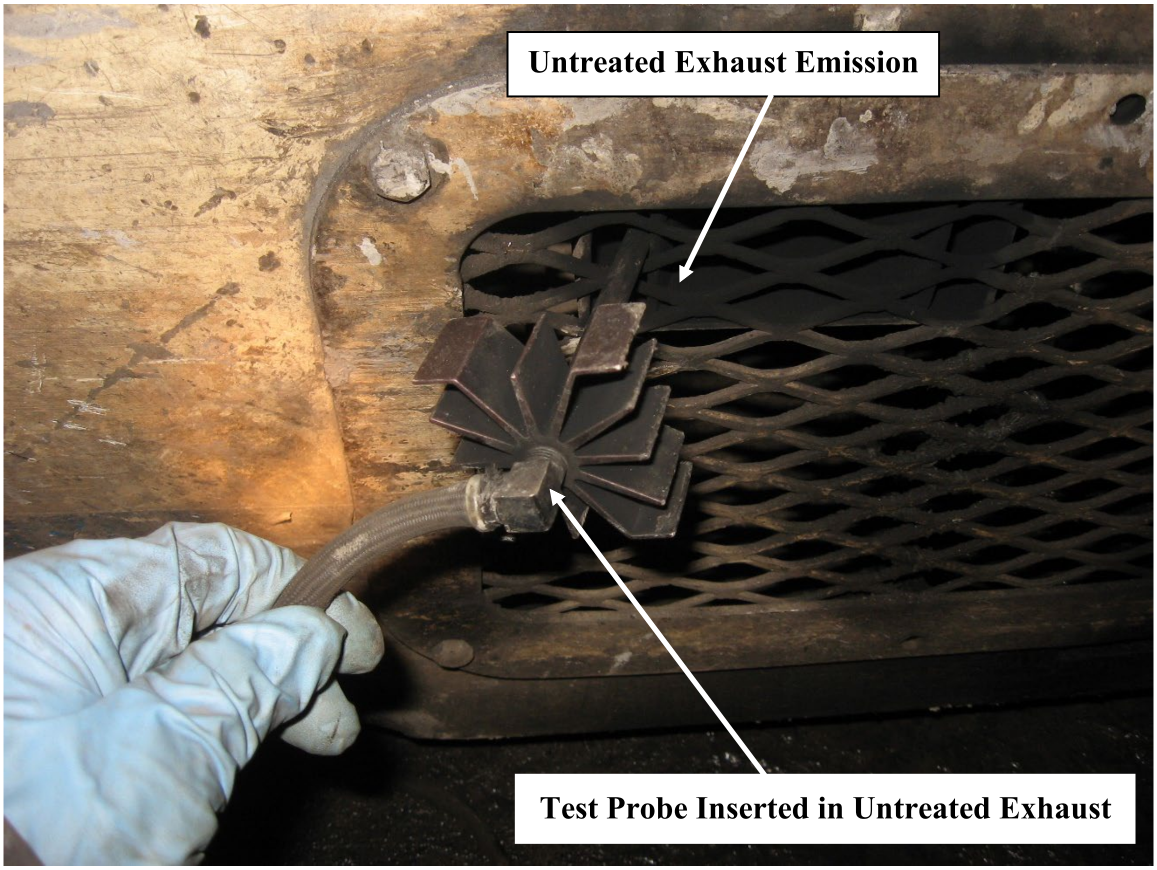


The undiluted exhaust emissions should be evaluated, and a CO PPM and RPM reading entered into the weekly record book. This information will be determined during an actual load test. An approval should not be granted for any diesel equipment with an emission test result of 2500 PPM or more.

Engine Compartment



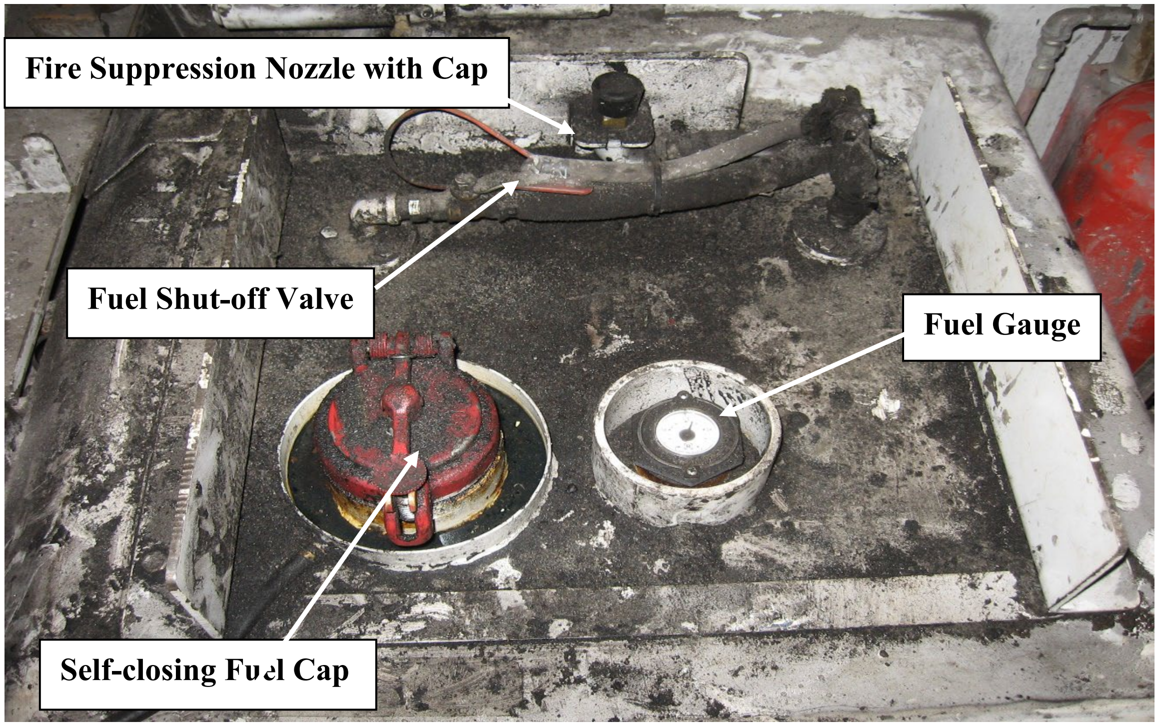
Example of Untreated Exhaust Emission Testing



Forensics CO detector

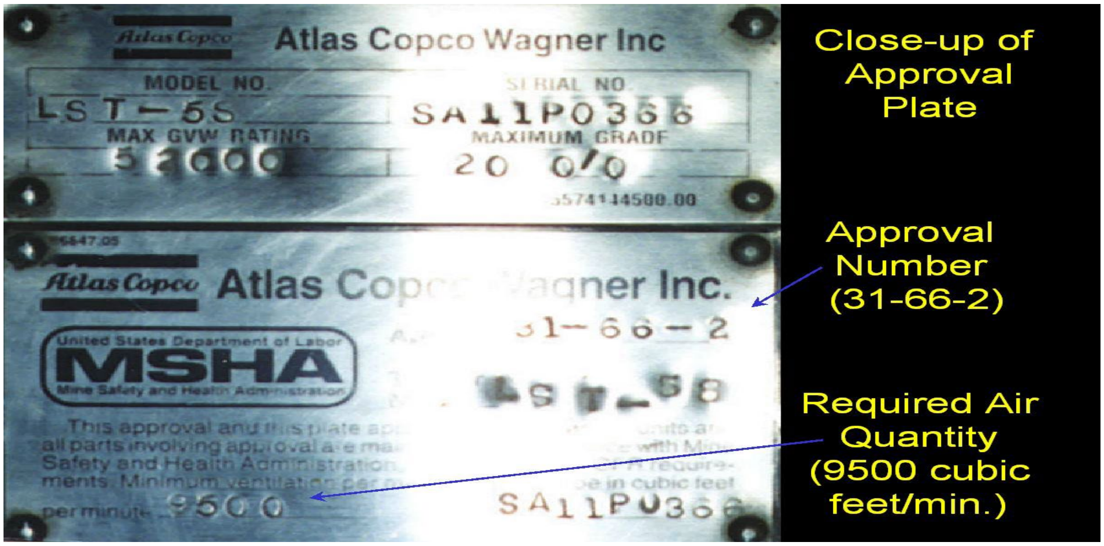
Typical Operator's Control Station

Fueling Compartment



Hydraulic Control Sander

Intake Vacuum and Exhaust Back Pressure Monitoring



Permissible Equipment: This section applies only to permissible equipment approval. These items listed should be in place and pass all listed functions to obtain approval. Listed below are these items and functions and where the inspection procedures can be found in the Permissible Equipment

Permissible-type diesel equipment is required to be equipped with an approval plate to verify that the machine is a permissible-type and has been approved. Required data on the approval plate includes the approval number for the machine and the air quantity required to properly ventilate the machine to dilute and carry away diesel exhaust contaminants.

Checklist:

- Electrical component permissibility maintained
- Emergency engine shutdown operable
- Flame arresters (intake and exhaust) provided
- Low-Level shutdown (water bath/ scrubber)

Permissible equipment is required to be equipped with a valve operable from the operator's compartment to be used to shut off the intake air supply to the engine thereby causing the engine to shut down. A means provided in the operator's compartment to activate the valve is shown. When activated, the intake air valve is mechanically closed shutting off airflow to the engine's combustion chambers.

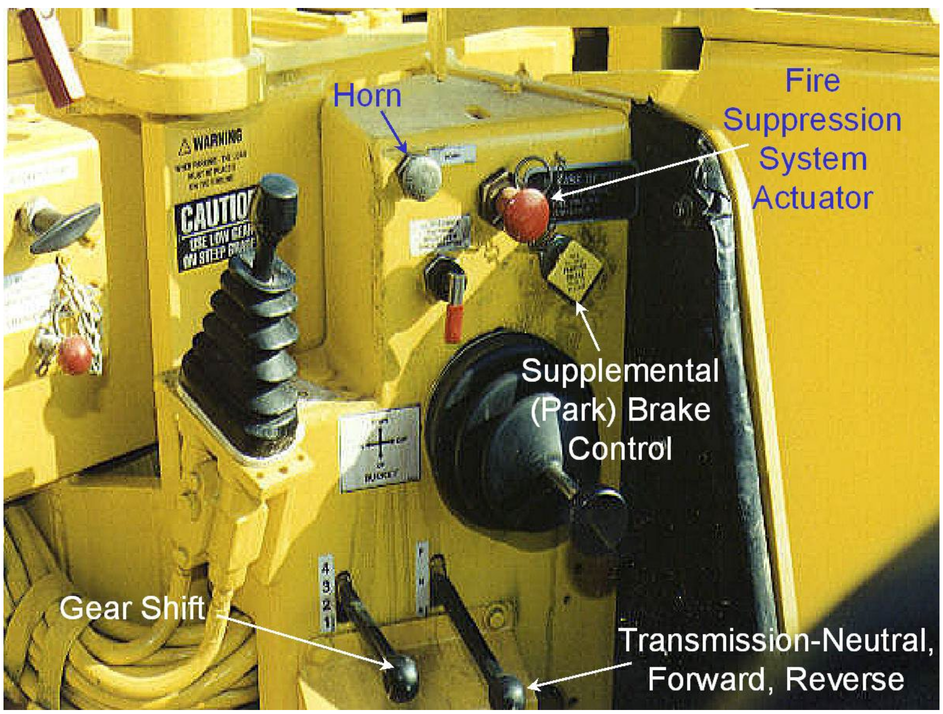
The operator's compartment is also equipped with a normal shutdown control located beside the operator's seat. When activated, fuel flow to the engine is shut off causing the engine to shut down.

The intake air system for a diesel engine is equipped with an air cleaner service indicator, which will show when the air cleaner (filter) needs to be replaced. The indicator used on the Wagner scoop is shown. The indicator is set in accordance with the engine manufacturer's specifications. This indicator will show red with the engine running at high idle when the filter needs to be replaced.

Primary and Secondary
INTAKE FILTER

Shown are close-up views of typical controls. In addition to service brakes, diesel equipment is required to be equipped with a supplemental braking system (park brake) with a means of activation in the operator's compartment. This is shown along with the actuator for the fire suppression system, the warning device (horn), and the transmission directional and gearshift levers located to the right of the operator in the operator's compartment.

The machine must be equipped with a neutral start feature to prevent inadvertent movement of the machine during startup. The neutral start on this machine is achieved through control of pressure to the transmission control valve declutch spool.



Supplemental brakes (park brakes) are required to be tested weekly. The brakes are tested by applying the brake with the machine stationary, placing the transmission in the proper gear for testing (refer to service/maintenance manual and/or the machine's approved permissibility checklist). The directional control selector is placed in forward or reverse. The accelerator is then gradually depressed to full throttle, allowing the engine to put the transmission torque converter into a stall condition. If the parking brake is operating satisfactorily, the unit will not move when the above procedure is followed. If movement is detected, the parking brake must be repaired or adjusted.

Some machines are equipped with a park brake test valve so this test may be performed. The design of the supplemental braking system prevents tramming when the brake is engaged. The brake test valve overrides this feature for test purposes.

WARNING**: Brake tests are to be conducted on a relatively level surface, away from traffic areas where other machines or persons may be moving about. Consider the possible consequences of testing a machine with defective brakes and select an area where the machine being tested would not cause an accident due to this defect.**

NOTE: Service brakes are tested in the same manner.

NOTE: A few machines have undergone manufacturer-approved modifications that require variations in the brake testing procedure. The manufacturer-provided documentation would be followed in these cases.

Weekly Examinations and Maintenance of Diesel Equipment:

1. An hour meter reading from the diesel equipment should be entered into the record book during weekly examinations.

2. Certification of diesel engine mechanic employed for the mine should be verifiable and available for review.

3. A maintenance manual for each piece diesel equipment should be present at the mine for review by interested persons.

4. A record keeping process should be established.

Ventilation of Diesel Equipment: Evaluation of the adequacy of ventilation of the mine should be made. This should be at the mine inspector's discretion and may require an underground evaluation.

Emission testing and evaluation: Written procedures for repeatable load testing as required by 4 VAC 25-90-60 should be available for review. Instrumentation should also be available that is capable of accurately detecting expected concentrations of carbon monoxide. The RPM reading should be close to the RPM reading taken during the actual load test.

Fuel specifications: Operator shall maintain on the mine site and make available for inspection a statement from the diesel fuel supplier certifying the sulfur content and flash point of the fuel to be used underground. Fuel shall contain sulfur concentration of .05 or less by weight and a flash point of 100° F or greater at standard temperature and pressure.

Effective Written Procedures

The following is one example of a written procedure for weekly testing and evaluation of diesel-powered engine.

1. **The method for which a repeatable load test is conducted must include an engine RPM reading. A repeatable load test, including an RPM reading, will be conducted weekly by the following method:**
    a. The repeatable load test for this machine will be performed when the engine is at normal operating temperature. The instrument probe will be placed into the undiluted exhaust stream with the engine operating at 1200 RPM and the machine transmission place in Forward / 2nd gear. The service brake will be engaged while a carbon monoxide measurement of the undiluted exhaust is taken from a safe location.

2. **Sampling and analytical methods, including calibration of instrumentation**:
    a. An instrument capable of accurately detecting carbon monoxide in the expected concentrations will be used. Instrumentation will be used with capabilities of detecting up to 2500 ppm. These instruments will be calibrated and maintained in accordance with manufacturer's specifications.

3. **The method of evaluation and interpretation of sampling results:**
    a. Undiluted exhaust emission samples will be compared with previous samples to establish trends in engine performance. Should any sample reflect carbon monoxide concentrations of two times the established baseline or 2500 PPM or more, this unit of diesel equipment will be removed from service and engine performance improved.

4. **The concentration or changes in concentration of carbon monoxide that will indicate a change in engine performance and an action plan to address changes in performance:**
    a. The operator will establish a baseline level, subject to approval by the Chief, by comparing the MSHA engine approval data with the average of the first four undiluted exhaust emission tests required by. This procedure will establish an action level not to exceed the lesser of two times the baseline or 2500 PPM of carbon monoxide.

5. **The maintenance of records necessary to track engine performance will be:**
    a. Recorded in a secure book that is not susceptible to alteration or recorded electronically in a computer system that is secure and not susceptible to alteration.
    b. Retained at a surface location at the mine for at least one year and made available for inspection by interested persons.

Example of an established baseline:

The established baseline level of carbon monoxide emissions for the following diesel unit AL LEE MINI-TRAC, equipment # MT-6, Serial number: BR549 is 248 PPM. Should emission levels exceed the lesser of 2 times the established baseline, or 2500 PPM, the machine will be removed from service and engine performance improved to acceptable limits.

Johnson Industries Supersteer Diesel

<u>Sample MSHA Diesel Powered Machine Checklist</u>

<u>MSHA Outby Machine Checklist</u>

§75.1909	Non-permissible diesel-powered equipment; design and performance requirements.
§75.1910	Non-permissible diesel-powered equipment; electrical system design and performance requirements.

Machine: ____

Model No.: ____

Serial No.: ____

Owner: ____

Condition: ____

Date of Inspection: ______________________________________

Location: ____

Investigators: ____

MSHA SAMPLE CHECKLIST

Section Rule Changes Comments Minor Major

1909	Non-permissible diesel-powered equipment; Design and performance requirements.	
(a)	Non-permissible diesel-powered equipment; Except for the special category of Equipment under Sec. 75.1908 (d), must be Equipped with the following features:	
(a)(1)	An engine approved under subpart E of part 7 of this title.	Approval No.
(a)(1)	Equipped with an air filter sized in accordance with the engine recommendations.	Air filter model No.: CFM rating: manufacturer's
(a)(1)	An air filter service indicator set in accordance with the engine manufacturer's recommendations	_____________ "Hg
(a)(2)	At least one portable multipurpose dry chemical type (ABC) fire extinguisher listed or approved by a nationally recognized independent testing laboratory with a 10A:60B:C or higher rating.	Date of last inspection – UL, FM tag-
(a)(2)	The fire extinguisher must be located within easy reach of the equipment operator and protected from damage	
(a)(3)	A fuel system specifically designed for diesel fuel meeting the following requirements	
(a)(3)(i)	A fuel tank and fuel lines that do not leak.	
(a)(3)(ii)	A fuel tank that is substantially constructed and protected against damage by collision;	
(a)(3)(iii)	A vent opening that maintains atmospheric pressure in the fuel tank, and that is designed to prevent fuel from splashing out of the vent opening;	
(a)(3)(iv)	A self-closing filler cap on the fuel tank;	

(a)(3)(v)	The fuel tank, filler and vent must be located so that leaks or spillage during refueling will not contact hot surfaces;	
(a)(3)(vi)	Fuel line piping must be either steel-wire reinforced; synthetic elastomer-covered hose suitable for use with diesel fuel that has been tested and has been determined to be fire-resistant by the manufacturer; or metal;	
(a)(3)(vii)	Fuel line piping must be clamped;	
(a)(3)(viii)	Primary fuel lines must be located so that fuel line leaks do not contact hot surfaces;	
(a)(3)(viii)	The fuel lines must be separated from electrical wiring and protected from damage in ordinary use;	
(a)(3)(viii)	A manual shutoff valve must be installed in the fuel system as close as practicable to the tank;	
(a)(3)(ix)	A water separator and fuel filter(s) must be provided.	
(a)(4)	A sensor to monitor the temperature and provide a visual warning of an overheated cylinder head on air-cooled engines;	
(a)(5)	Guarding to protect fuel, hydraulic, and electric lines when such lines pass near rotating parts or in the event of shaft failure;	
(a)(6)	Hydraulic tanks, fillers, vents and lines located to prevent spillage or leaks from contacting hot surfaces;	
(a)(7)	Reflectors or warning lights mounted on the equipment which can be readily seen in all directions;	
(a)(8)	A means to direct exhaust gas away from the equipment operator, persons on board the machine, and combustible machine components;	

(a)(9)	A means to prevent unintentional free and uncontrolled descent of personnel-elevating work platforms;	
(a)(10)	A means to prevent the spray from ruptured hydraulic or lubricating oil lines from being ignited by contact with engine exhaust system component surfaces.	
(b)	Self-propelled non-permissible diesel-powered equipment must have the following features in addition to those in paragraph (a):	
(b)(1)	A means to ensure that no stored hydraulic energy that will cause machine articulation is available after the engine is shut down;	
(b)(2)	A neutral start feature which ensures that engine cranking torque will not be transmitted through the power train and cause machine movement on vehicles utilizing fluid power transmissions;	
(b)(3)	For machines with steering wheels, brake pedals, and accelerator pedals, controls which are of automobile orientation;	
(b)(4)	An audible warning device conveniently located near the equipment operator;	
(b)(5)	Lights provided and maintained on both ends of the equipment.	
(b)(5)	Equipment normally operated in both directions must be equipped with headlights for both directions;	
(b)(6)	Service brakes that act on each wheel of the vehicle and that are designed such that failure of any single component, except the brake actuation pedal or other similar actuation device, must not result in a complete loss of service braking capability;	

(b)(7)	Service brakes that safely bring the fully loaded vehicle to a complete stop on the maximum grade on which it is operated;	Vehicle grade rating
(b)(8)	No device that traps a column of fluid to hold the brake in the applied position shall be installed in any brake system, unless the trapped column of fluid is released when the equipment operator is no longer in contact with the brake activation device.	
(c)	Self-propelled non-permissible heavy-duty diesel-powered equipment under Sec. 75.1908 (a), except rail-mounted equipment, shall be provided with a supplemental braking system that:	
(c) (1)	Engages automatically within 5 seconds of the shutdown of the engine;	
(c)(2)	Safely brings the equipment when fully loaded to a complete stop on the maximum grade on which it is operated;	Vehicle grade rating
(c)(3)	Holds the equipment stationary, despite any contraction of brake parts, exhaustion of any non-mechanical source of energy, or leakage;	
(c)(4)	Releases only by a manual control that does not operate any other equipment function;	
(c)(5)	Has a means in the equipment operator's compartment to apply the brakes manually without shutting down the engine; and a means to release and re-engage the brakes without the engine operating;	
(c)(6)	Has a means to ensure that the supplemental braking system is released before the equipment can be trammed and is designed to ensure the brake is fully released at all times while the equipment is trammed.	
(d)	Self-propelled non-permissible light-duty diesel-powered equipment under	

	Sec. 75.1908 (b), except rail-mounted equipment, must be provided with a parking brake that holds the fully loaded equipment stationary on the maximum grade on which it is operated despite any contraction of the brake parts, exhaustion of any non-mechanical source of energy, or leakage.	
(e)	The supplemental and park brake systems required by paragraphs (c) and (d) must be applied when the equipment operator is not at the controls of the equipment, except during movement of disabled equipment.	
(f)	Self-propelled personnel-elevating work platforms must be provided with a means to ensure that the parking braking system is released before the equipment can be trammed and must be designed to ensure the brake is fully released at all times while the equipment is trammed.	
(g)	Any non-permissible equipment that discharges its exhaust directly into a return air course must be provided with a power package approved under subpart F of part 7 of this title.	
(h)	Self-propelled non-permissible heavy-duty diesel-powered equipment meeting the requirements of Sec. 75.1908(a) must be provided with an automatic fire suppression system meeting the requirements of Sec. 75.1911	
(i)	Self-propelled non-permissible light-duty diesel-powered equipment meeting the requirements of Sec. 75.1908(b) must be provided with an automatic or manual fire suppression system meeting the requirements of Sec. 75.1911.	
(j)	Non-permissible equipment that is not self-propelled must have the following	

	features in addition to those listed in paragraph (a):	
(j)(1)	A means to prevent inadvertent movement of the equipment when parked.	
(j)(2)	Safety chains or other suitable secondary connections on equipment that is being towed;	
(j)(3)	An automatic fire suppression system meeting the requirements of Sec. 75.1911.	
1910	Non-permissible diesel-powered equipment; electrical system design and performance requirements.	
1909 (Continued)	Electrical circuits and components associated with or connected to electrical systems on non-permissible diesel-powered equipment utilizing storage batteries and integral charging systems, except for the special category of equipment under Sec. 75.19089(d), must conform to the following requirements:	
(a)	Overload and short circuit protection must be provided for electric circuits and components in accordance with Sections. 75.518 and 75.518-1 of this part;	Attach wiring schematics
(b)	Each electric conductor from the battery to the starting motor must be protected against short circuit by fuses or other circuit-interrupting devices placed as near as practicable to the battery terminals;	Fuse rating: Starter motor/kw:
(b)	Each branch circuit conductor connected main circuit between the battery and charging generator must be protected against short circuit by fuses or other automatic circuit-interrupting devices;	Attach wiring schematics

UNIT X

Daily and Weekly Examination Examples

Sample of a daily intake / exhaust system visual inspection. To be completed by an authorized person each day the machine is in operation.

Diesel Engine Mechanic Certification
Daily/Weekly Examination Report

RECORD OF DAILY AND WEEKLY EXAMINATIONS OF DIESEL-POWERED EQUIPMENT

Undiluted exhaust emissions of diesel engines in diesel-powered equipment used in underground coal mines shall be tested and evaluated weekly by an authorized person.
The carbon monoxide (CO) level of the undiluted exhaust emissions cannot exceed the lesser of two times the baseline level of 130 PPM or 2500 PPM (30 CFR- Part 7 prohibits undiluted exhaust emissions to exceed 2500 PPM-CO).

Diesel Unit Tested CLA LT-5640 Mantrip serial #40500 Hour Meter Reading _____360_____________

Raw Exhaust Emissions (Right Side) ____220____PPM of Carbon Monoxide at 1500 RPM
Raw Exhaust Emissions (Left Side) __________ PPM of Carbon Monoxide at _____RPM

Date: Examiner:

Engine intake and exhaust systems shall be inspected visually by an authorized person at least once each day that the equipment is operated (general condition, filters, leaks, etc.)

☒ Intake ☒ Exhaust (to include both sides of dual exhaust system)

Comments: __O.K.____Visual inspection only.______________________

Date: 9/5/24 Examiner: John Davidson

☐ Intake ☐ Exhaust (to include both sides of dual exhaust system)

Comments:____

Date Examiner

Example of a Weekly Examination Checklist to be Conducted by a Certified Diesel Engine Mechanic

RECORD OF DAILY AND WEEKLY EXAMINATIONS OF DIESEL-POWERED EQUIPMENT
Inspection of underground equipment: Once each week, or more often if necessary, a certified diesel engine mechanic shall inspect diesel powered equipment to assure its safe operating condition.

Weekly Equipment Examinations: Mark the applicable items required to be examined.

- ☒ Free of combustible material
- ☒ Audible warning device
- ☒ Engine start and stop mechanism
- ☒ Guards over moving parts
- ☐ Re-railing device (self propelled rail equipment only)
- ☐ Sanding devices (self propelled rail equipment only)
- ☒ Headlights on each end
- ☒ Park and service brakes
- ☒ Fire suppression system
- ☒ Intake and exhaust couplings in good condition
- ☒ Self-closing filler cap on fuel tank
- ☒ Engine shall not start unless transmission in neutral

Permissible and emission components of diesel-powered equipment shall be inspected weekly by a certified diesel engine mechanic in accordance with the instructions of the manufacturer and all applicable federal and state requirements.

- ☐ Electrical component permissibility maintained
- ☐ Emergency engine shutdown operable
- ☐ Flame arresters (intake and exhaust) provided
- ☐ Low-level shutdown (water bath/scrubber) operable

Maintenance and Repairs needed and/or performed:

Replaced spring on fuel tank filler cap or replaced cap assembly
Replaced air filter
Repaired park brake
Cleaned engine compartment – removed oil, grease, coal dust
Replaced/installed guard over left side exhaust

Comments: Replaced air filter at 360 hours

Date **9/4/24** Diesel Engine Mechanic Certification No. **10001**
Examiner **John Robinson II**

Example of a Weekly CO Emissions Record

Diesel Engine Mechanic Certification
Daily/Weekly Examination Report

RECORD OF DAILY AND WEEKLY EXAMINATIONS OF DIESEL POWERED EQUIPMENT

Undiluted exhaust emissions of diesel engines in diesel-powered equipment used in underground coal mines shall be tested and evaluated weekly by an authorized person.
The carbon monoxide (CO) level of the undiluted exhaust emissions cannot exceed the lesser of two times the baseline level of ________365_____PPM or 2500 PPM. (30 CFR – part 7 prohibits undiluted exhaust emissions to exceed 2500 ppm – CO).

Diesel Unit Tested ________LT-101__________Hour Meter Reading_____754_____________

Raw Exhaust Emissions (Right Side)___362 __PPM of Carbon Monoxide at __1800 _RPM
Raw Exhaust Emissions (Left Side)_________PPM of Carbon Monoxide at _________RPM

Date	Examiner	Certification No.
9/4/24	John Robinson II	10001

Engine intake and exhaust systems shall be inspected visually by an authorized person at least once each day that the equipment is operated (general condition, filters, leaks, etc.)

[X] Intake   [X] Exhaust (to include both sides of dual exhaust system)

Comments:________________________________

Date: 9/5/24   Examiner: James A Stanely

[ ] Intake   [ ] Exhaust (to include both sides of dual e

Comments:________________________________

Date   Examiner

> Note that the Daily Inspection of the intake / exhaust system is not required to be conducted by a certified person, but an "authorized" person. A person trained to conduct a proper examination of the systems.

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